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RIO BLANCO OIL SHALE COMPANY
MIS RETORT ABANDONMENT PROGRAM

SEPTEMBER 30, 1983

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RETORT ABANDONMENT PROGRAM
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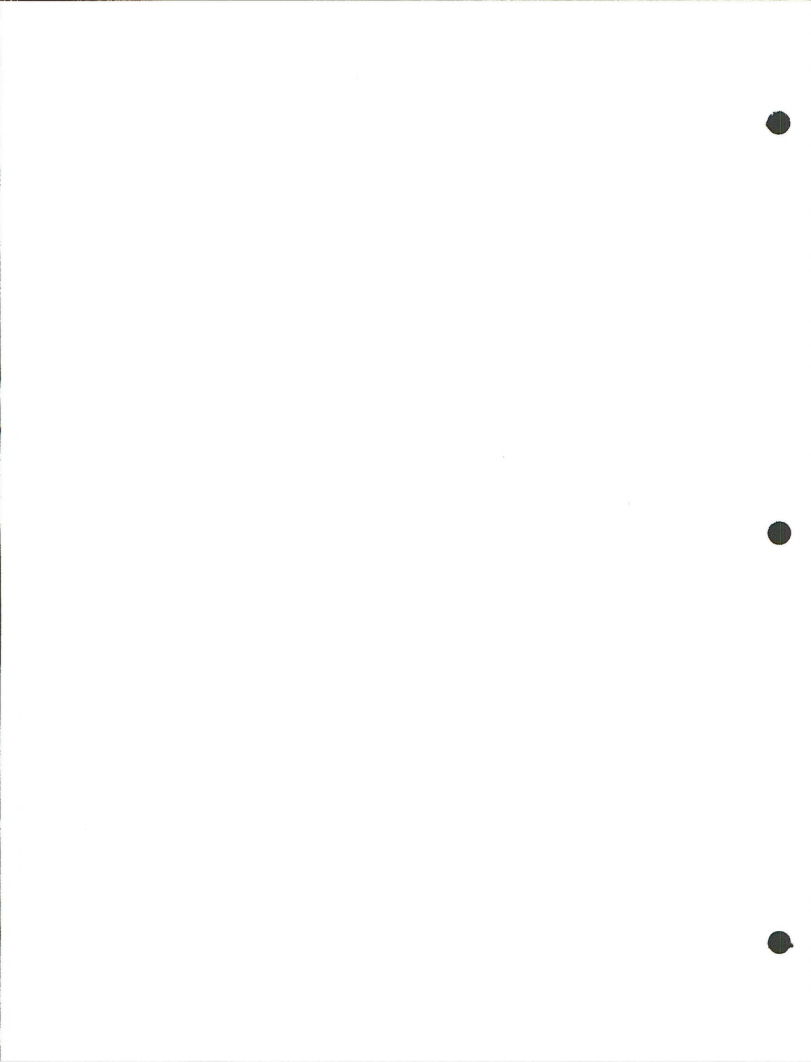


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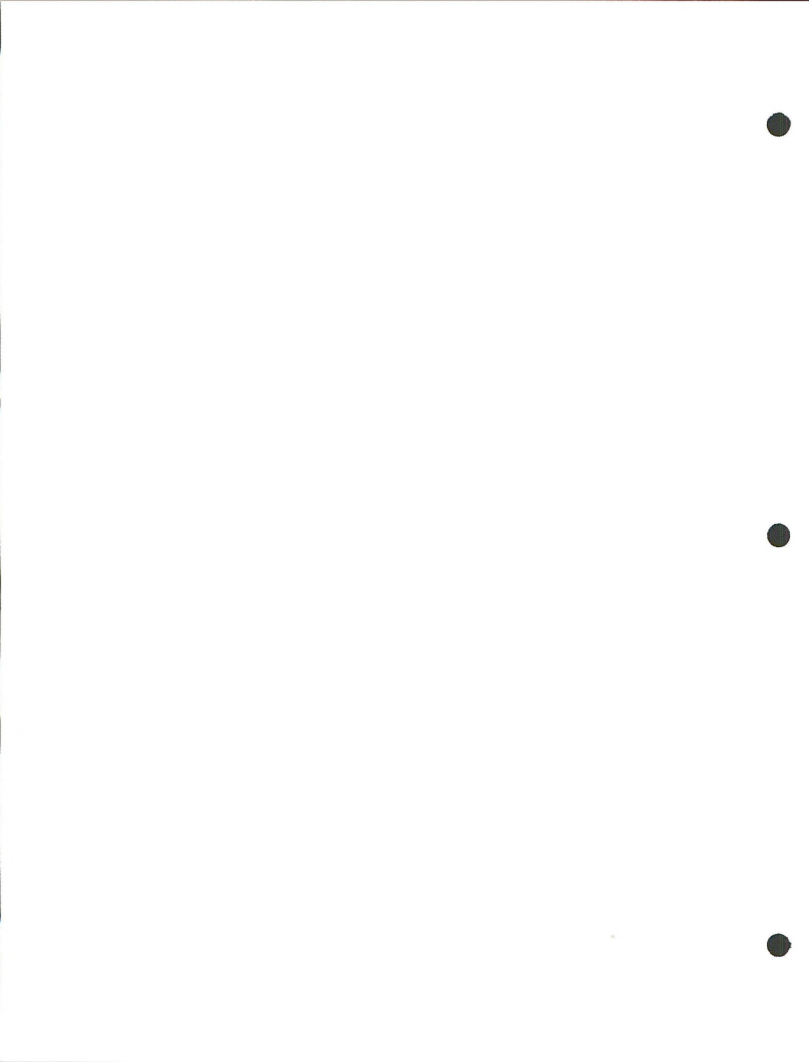
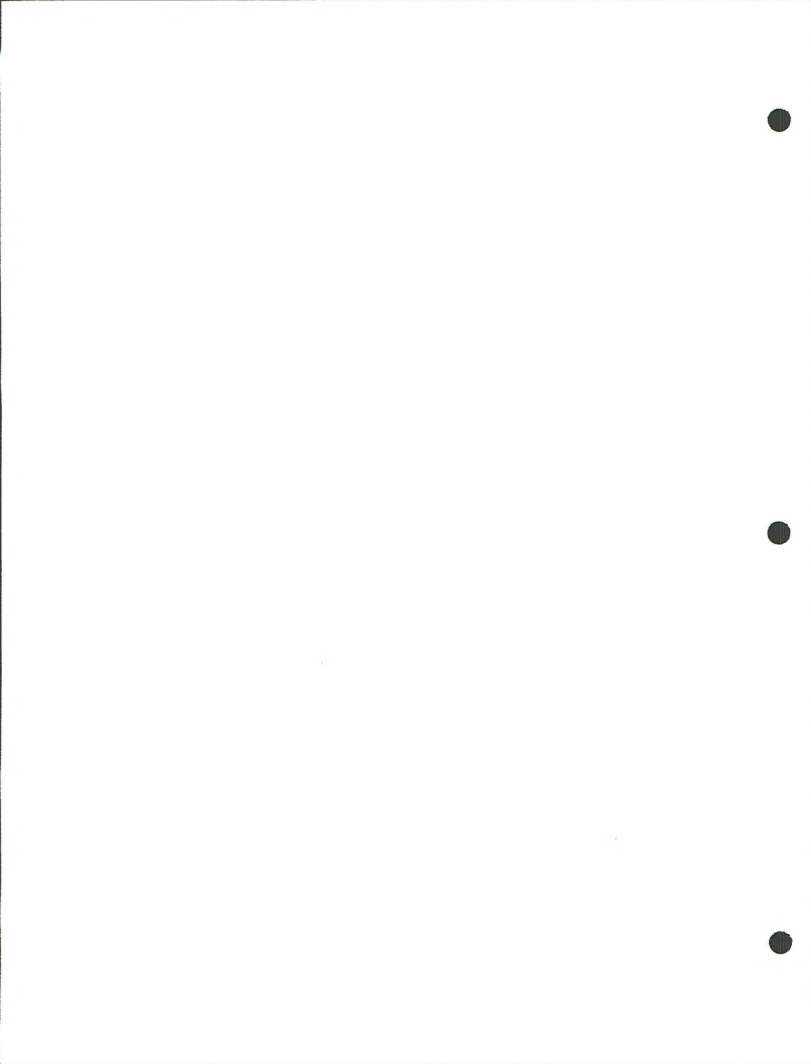


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RETORT ABANDONMENT PROGRAM

1.0 Introduction

The Rio Blanco Oil Shale Company (RBOSC) has developed a plan for the abandonment of the modified in situ retorts on Federal Prototype Oil Shale Lease Tract C-a. This proposal is submitted to the Bureau of Land Management, Branch of Oil Shale in accordance with the conditions of approval for the Revised Detailed Development Plan dated September 22, 1977.

1.1 Abstract

RBOSC proposes to abandon the two modified in situ retorts on Tract C-a in the following manner:

- o Pump existing water out of retorts
- o Allow retorts to flood completely
- o Recirculate water through retort to leach most of soluble material from the rubble
- o Pump all leachate from the retorts and product collection system
- o Flood retorts
- o Monitor groundwater in area around retorts until it has been determined that an unacceptable migration of harmful substances is not likely to be detected in the monitoring wells adjacent to the retorts

The criteria for cessation of monitoring are spelled out in the proposal.

1.2 Executive Summary

A plan for the abandonment of the modified in situ retorts on Tract C-a has been developed in accordance with the stipulations attached to the approval of the Revised Detailed Development Plan dated September 22, 1977.

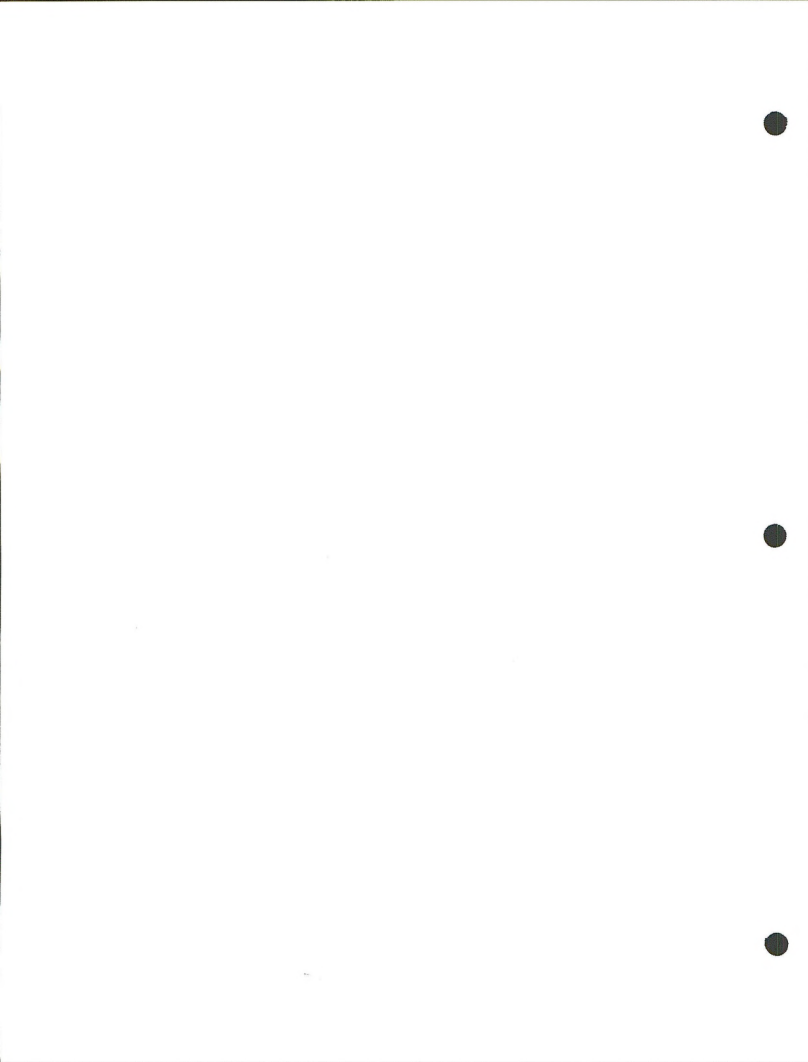


Several retort abandonment scenarios were evaluated before selecting the proposed plan.

- o Flood retorts and monitor
- o Leach by circulation followed by flood retorts and monitor
- o Flood retorts, leach by circulation, pumpdown, flood, and monitor
- o Pumpdown, flood, leach by circulation, pumpdown, flood, and monitor
- o Continuous retort pumping
- o Grout retort rubble
- o Curtain grouting around retorts

Based on experience since the end of retort operation, laboratory research, and hydrologic modeling the Pump - Flood - Leach - Pump - Flood - Monitor option was selected for Tract C-a MIS retort abandonment. The grouting options are potential fallback solutions should the proposed monitoring program demonstrate the need for such action.

An extensive groundwater monitoring program is planned. Daily, weekly, and monthly sampling and analysis activities are an integral part of the monitoring program. Specific inorganic and organic substances have been selected as indicators of leachate migration from the retorts. Response and termination criteria are also presented.



2.0 Background Information

2.1 Present Conditions

2.1.1 Retorts

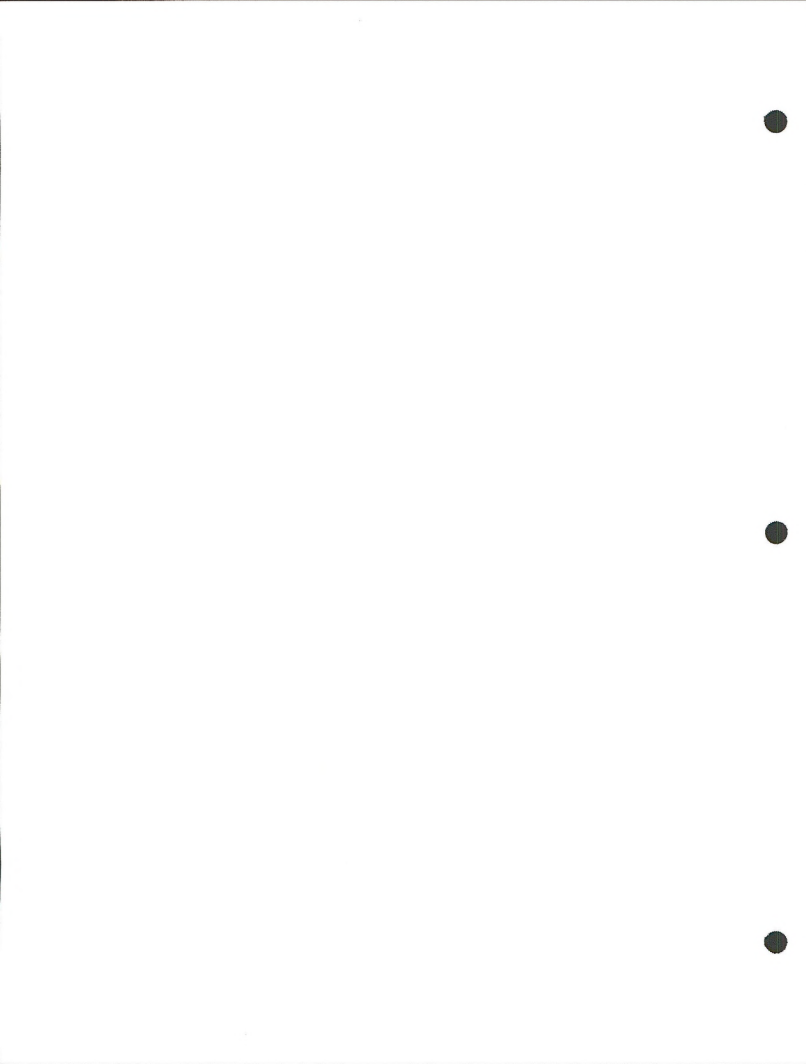
The retort are currently flooded to an elevation of 6175 feet which is approximately 100 feet above the retort bottoms. This condition has existed since mid-November 1982 when a series of mine pump failures in late October 1982 resulted in flooding the mine to an elevation of 6361 feet and the retorts to 6262 foot elevation. Subsequent pumping has resulted in the mine water levels being maintained at 6176 foot elevation which is one foot above retort water level. This level differential prevents flow from the retort into the mine water system. Figure 15 shows the mine and retorts.

2.1.2 Ponds

RBOSC constructed twelve Hypalon lined ponds to store and evaporate water from the modified in situ (MIS) retort and the surface processing plant. These ponds have a total capacity of 24.9 million gallons. A clay lined pond was also built to store scrubber blowdown water and all surface drainage from the processing plant. This pond, which is known as the East Pond, has a capacity of 11.2 million gallons. Figure 1 shows the general layout of the surface facilities at Tract C-a.

2.1.2.1 Volumes

The twelve evaporation ponds currently contain 18.1 million gallons of water. Figure 2, which is based on projected precipitation, retort inflows and evaporation, shows that the capacity of the evaporation ponds will be exceeded by March of 1984 if the current mode of retort management continues. Pre-flood leaching by circulating retort water through the retorts could extend the time to pond overflow by about one week because some of the water flowing into Retort 1 will be converted to steam and some will be absorbed by the rubble in the unsaturated regions of the retort.



The East Pond currently contains 5.0 million gallons of water. Because of the limited evaporation pond capacity and the continued high water flow rate into the retort, it will be necessary to transfer about 4 million gallons of water from the evaporation ponds into the East Pond before March 1984. Figure 3 shows the projected volume of water in the East Pond if the proposed transfers from the evaporation ponds is approved.

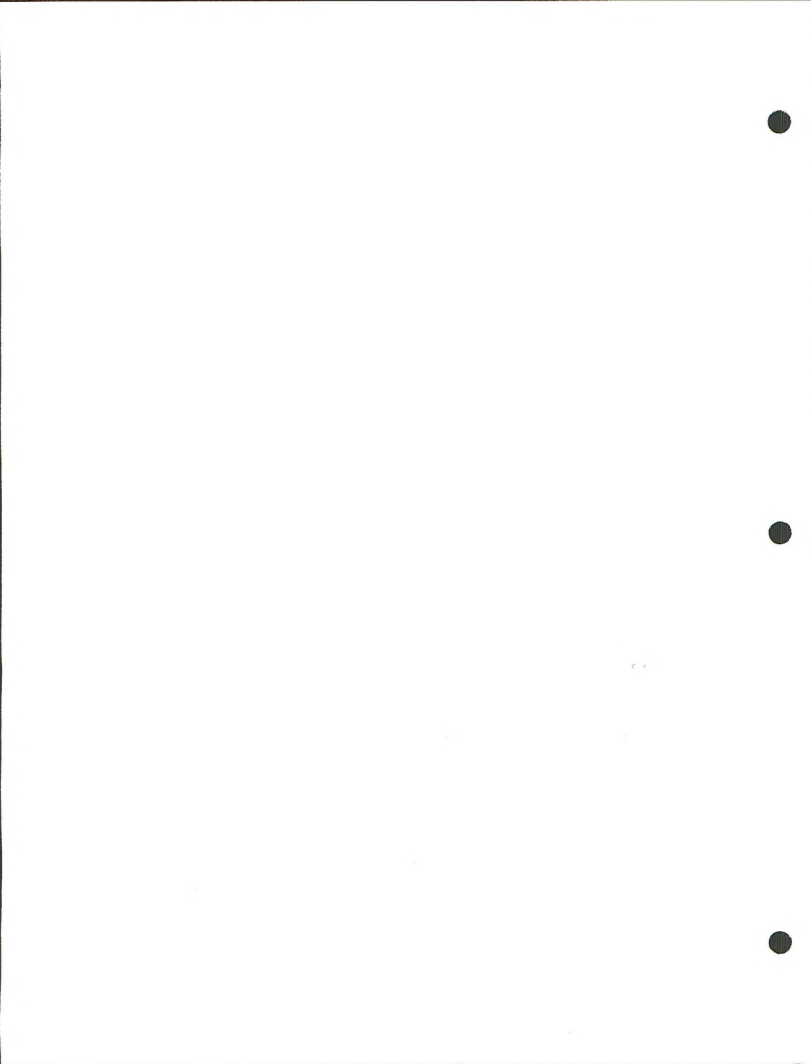
2.1.2.2 Water Quality

The water quality varies significantly from one pond to another. The specific conductance for each evaporation pond in microhos per centimeter are shown below.

TABLE 1
Evaporation Pond Specific Conductance
(July 1983)

<u>Pond</u>	<u>Specific Conductance</u>	
	<u>Micromhos/cm 25⁰C</u>	
1	44300	
2	24000	
3	9000	
4	7200	
5	43700	
6	43700	
7	7750	
8	4200	
9	5400	
10	3900	
11	3500	
12	4800	
East	6500	

Evaporation pond water quality analyses conducted in November 1982 did not indicate any severe problems. Phenol, benezene and toluene, the only priority pollutants detected, were found in concentrations of 29, 15 and 21 ppb respectively.



2.1.3 Groundwater

Groundwater levels and flow have increased significantly due to the abnormally wet weather since August 1982. Precipitation for the year ending with August 1983 totalled 19.6 inches. Normal annual precipitation is around 13 inches. The piezometric level at monitoring hole MDP-2C, which is located about 200 feet east of Retort 1 has risen 51 feet since March 1983 (See Figure 4). Inflow into the mine has increased from 900 gpm in January 1983 to 1700 gpm at the end of August 1983 (See Figures 5 and 6). Retort inflows increased from 10 gpm to 36 gpm during the same period. These inflows appear to have peaked in early September and are expected to decay at a slow rate until the runoff begins in the following spring (See Figures 7 and 8).

2.2 Retort Abandonment Related Research

The Modular Development Program (MDP) approval stipulated that retort abandonment research be performed. RBOSC has done considerable work on the questions surrounding retort abandonment. Much research work has been done independently by private, national and university laboratories that relates generically to the issue of Commercial MIS retort abandonment. Some of the reports and/or memos for in-house and RBOSC contracted research were sent to the Oil Shale Office, may be available for review. These RBOSC and outside studies are listed in Section 2.2.1.3.

2.2.1 Leachability of Retorted Rubble

The leachability of retorted MIS rubble has been investigated by many different organizations using retorted oil shale from several sources using various retorting methods. Rubble samples have not been obtained from Retorts 0 and 1 because high rubble temperatures coupled with the dangers related to the introduction of air into a hot retort prevented sampling. Since the upper half of Retort 1 still has rubble temperatures ranging from 190 to 800°F, it is not feasible to try to sample the rubble at this time. Natural cooling could take several years. If the retort is cooled by



flooding any rubble samples taken would only be representative of a flooded and partially leached retort.

2.2.1.1 Retort Leaching Experience at Tract C-a

Data collected since the retort was partially flooded best represents what can be expected during the proposed retort abandonment program. The unplanned flooding provided an excellent opportunity to study rubble leaching on a full scale rather than laboratory scale basis.

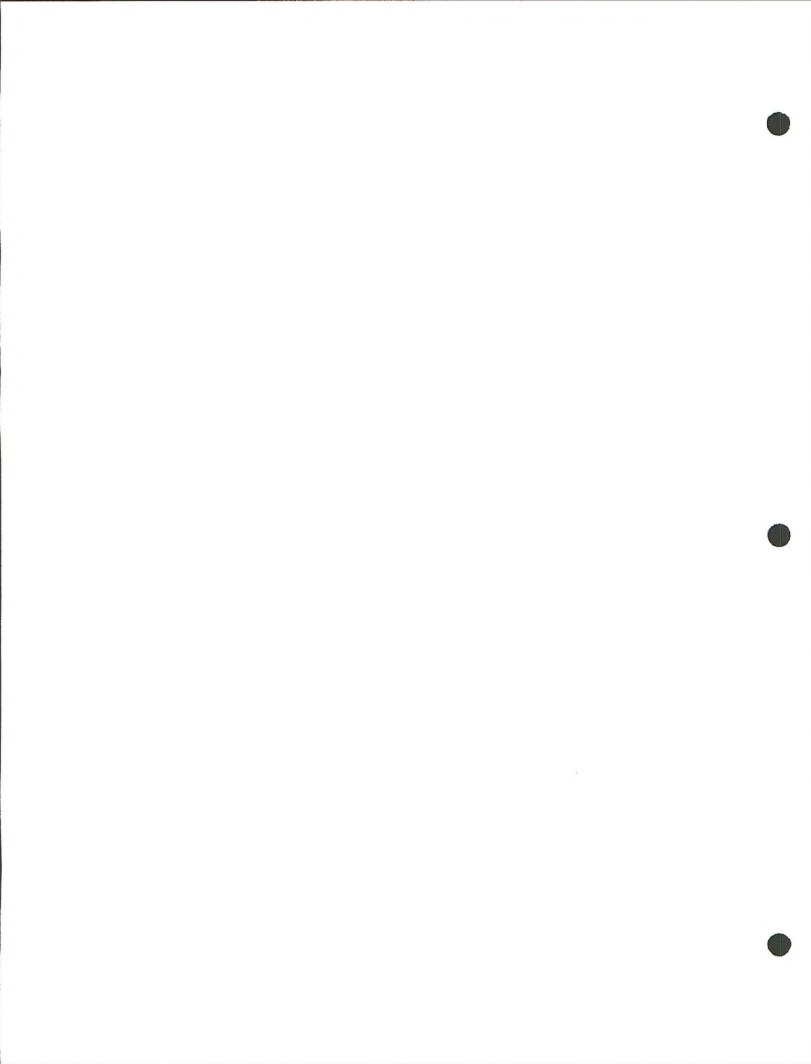
Water level, inflow rates and various water quality parameters have been recorded or sampled. The samples showed that, once the mine and retort water levels were stabilized, pH, specific conductance and the concentration of leachate indicators such as sodium, potassium, sulfates, and DOC generally increased over a period of about five months. The concentration levels of these indicators then stabilized and began to gradually decrease until the retort inflows increased significantly in early June 1983. The indicator concentrations then increased rapidly as did the retort water temperature, suggesting that the groundwater inflow was in the upper part of the retort where rubble temperatures ranged from 190°F to 800°F and no appreciable leaching had previously taken place. Section 2.2.1.2 describes the areas of probable groundwater flow into the retort and the rationale supporting these conclusions.

Figures 9 through 14 show the results of this mine and retort water sampling activity.

2.2.1.2 Groundwater Flow Into Retort 1

There are several areas around the retort system where groundwater or mine water are known or suspected to have entered the system.

- o The abutment zone of the bulkhead which separates the product pump room and the separator room on G-level of the mine.
Pressure testing prior to retorting indicated leakage through



fractures at pressures as low as 5 psi or 11.5 feet of hydraulic head.

- o During flooding and subsequent pumpdown of the mine and retort it was observed that significant changes in retort inflow occurred in the zones shown in Table 2.

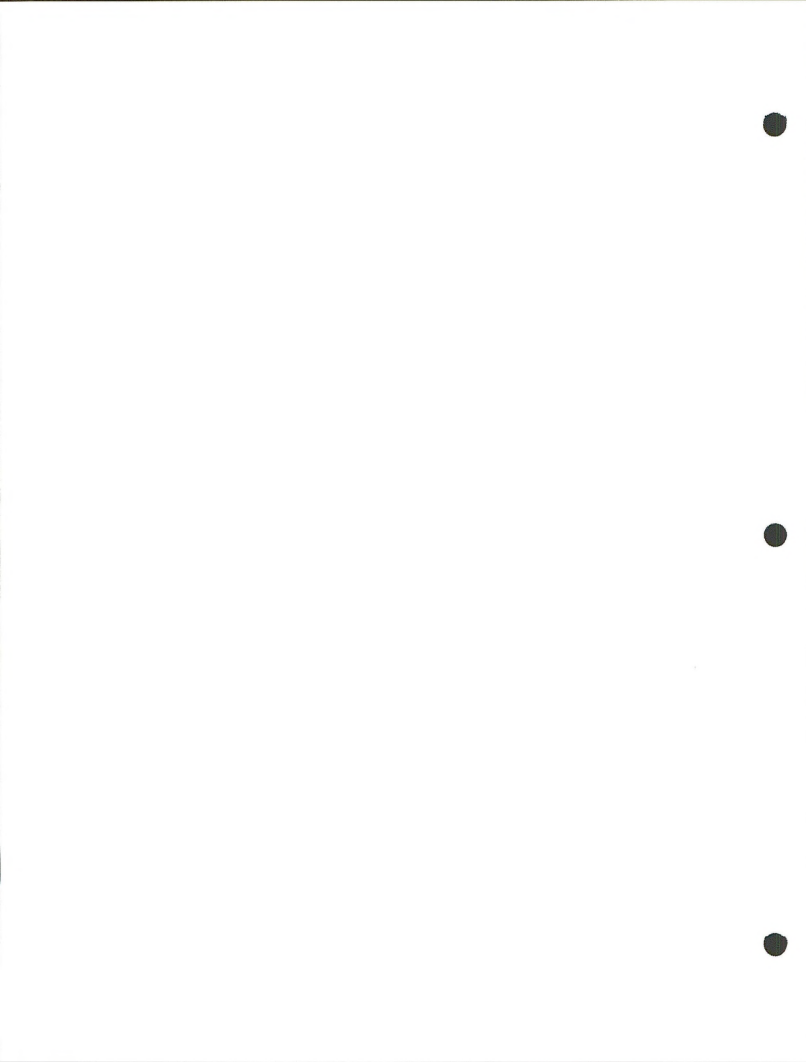
TABLE 2

Mine and Retort Water Levels

<u>Mine Water</u>	<u>Elevation Retort Water</u>	<u>P (PSI)</u>	<u>Retort Inflow Rate (GPM)</u>	<u>Date</u>
6264	6229	15.2	135	11/12/82
6240	6225	6.5	114	11/16/82
6226	6220	11.3	52	11/21/82
6220	6203	7.4	23	11/24/82
6210	6210	0	0	12/03/82

Table 2 shows that there was no significant inflow above the 6210 foot elevation during the fall of 1982.

- o The piezometric level of the upper aquifer around the mine rose significantly during the late spring and summer of 1983. This was due primarily to runoff resulting from the greater than normal precipitation in the area around Tract C-a. The most significant increase in inflow occurred immediately after a flash flood in Corral Gulch on May 31, 1983. This response suggests that there may be fracture type communication between the Corral Gulch alluvial aquifer and the upper aquifer in the immediate mine area. Concurrent with these events, thermocouples within Retort 1 showed rapid rubble cooling at one elevation and continued normal temperatures a short distance above. Retort water temperature increased rapidly following the



increased inflow, indicating that hotter rubble was exposed to the inflowing water.

TABLE 3
Retort Rubble Temperatures

<u>Thermocouple</u>	<u>Elevation (FT)</u>	<u>Temperature (°F)</u>	
		<u>5/11/83</u>	<u>6/12/83</u>
1611	6269	1112	858
1612	6246	680	169
7	6460 (Top of Retort)	197	108

Since TC #1612 is located directly below TC #1611 on the east side of Retort 1, it appears that the inflow location is between the elevations of 6269 and 6246 feet along the east wall of the retort. The possibility does exist, however, that the inflow is at a higher point and irregular channeling caused the water to bypass the upper thermocouple. The drop in rubble temperatures at the top of the retort from 197°F to 108°F during the summer of 1983 indicates some groundwater inflow into the top of the retort.

2.2.1.3 Retort Abandonment Related Research - Reference List

Retort Zero: Geochemistry of Sour Recycle Water
Memo to Darrel Porter from A.C. Riese, 1/14/82 Gulf Research and Development Company

Leaching and Microbiological Studies and Lawrence Livermore Laboratory Retorted Shale
D. C. Hoel and P.M. Bunting, November 1980 Gulf Science and Technology Company

Results of Mathematical Modeling for Retort Abandonment
Law Engineering Testing Company, November 17, 1981



Development of Source Term Models
MIS Closure Study
Law Engineering Testing Company, December 22, 1981

Feasibility Study: Abandonment of Retorts 0 and 1
Soletanche and Rodio, Inc., May 1981

Impact of In Situ Spent Shale Leachate on Groundwater Quality
For Modular Development Phase of Tract C-a
Ramírez and Abedi, April 1979
(For the Colorado Water Quality Control Commission)

Aquatic Ecosystem Effects of Process Water Produced by
Synthetic Fuel Technologies
Summary Progress Report 1/1/81 - 12/31/82
H. L. Bergman & J. S. Meyer - U. of Wyoming
EPA Cooperative Agreement #CR 808671

Investigation of Tracers to Identify Aquifer Contamination by
Retort Waters
Memo, D. G. Venardos to G. S. Slawson, December 20, 1982

Development of a Slurry Filling System for Modified In Situ
Oil Shale Mining
Soletanche & Rodio, Inc. and Rio Blanco Oil Shale Company, U.S.
B.O.M. Contract J029046, March 1982

2.2.2 Leachate Water Quality

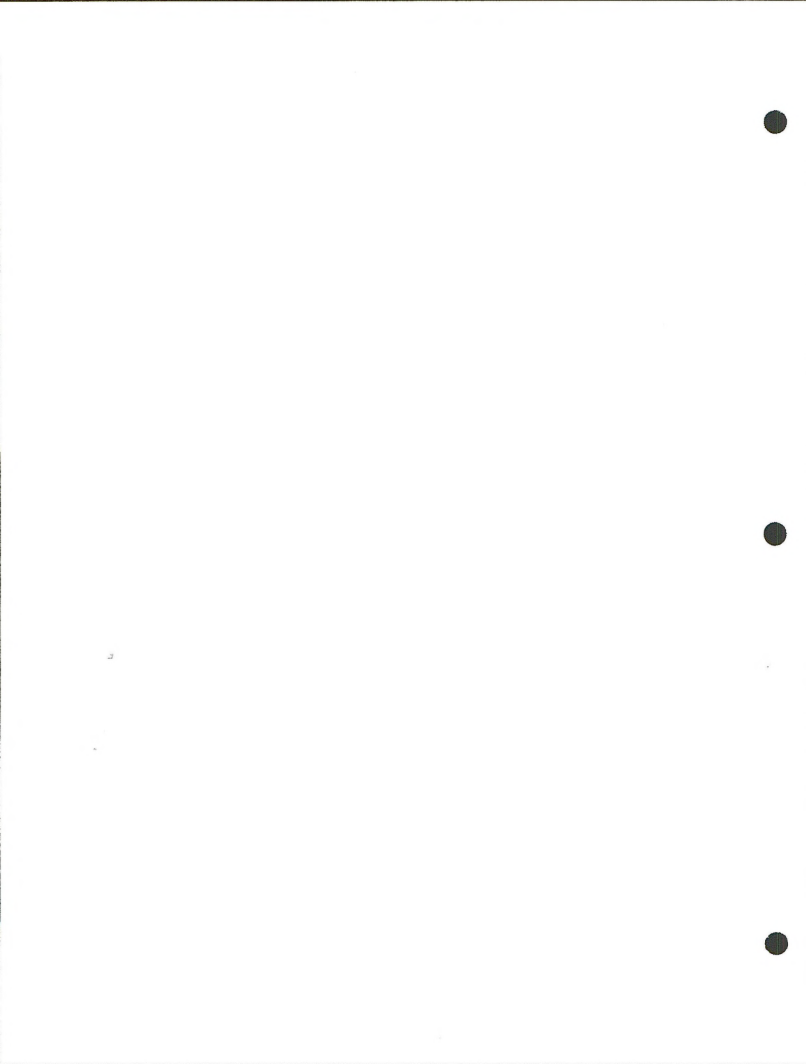
Much of the laboratory work to date has been concerned with water generated during or exposed to the actual retorting process. The water of current concern is being exposed to the rubble after 1 1/2 years of no retorting activity. The rubble has undergone leaching from partial flooding and increased groundwater flow into the upper parts of the retort. There is little resemblance between the water currently being pumped from Retort 1 and the water that was analyzed during and shortly after burning Retorts 0 and 1. Table 4 shows comparative water qualities for Retorts 0 and 1 immediately after retorting, and current Retort 1 and ground water.



TABLE 4
Comparative Water Quality

Groundwater	Retort 1		Retort 0	
	Current	End of Burn	End of Burn	
	Aug 1983	Dec. 1981	Jan. 1981	July
<u>1983</u>				
Specific Conductance	7650	4480	4000	1550
TDS (mg/l)	5856	1725	1388	1138
pH	8.6	8.8	9.2	7.8
Potassium (mg/l)	1300	20	39.5	0.29
Chloride (mg/l)	70.7	464	111	20
Sulfide (mg/l)	201	74.5	-	<0.02
Fluoride (mg/l)	10.1	26	16.1	1.2
Ammonia (mg/l)	40.6	479	7.2	<0.05
Boron (mg/l)	3.75	-	0.49	0.34
Molybdenum (mg/l)	0.8	<0.1	-	<0.1
DOC (mg/l)	78	532	217	8

Figures 7 through 14 show the changes in the retort water quality and inflow since the flooding in November 1982. Because the water that has flowed through actual undisturbed MIS retorts, results are more meaningful and better representation of expected abandonment conditions than projections based on spot shale samples from pilot-plant retorts tested in laboratories.



2.2.3 Rubble Characteristics

2.2.3.1 Retort 0

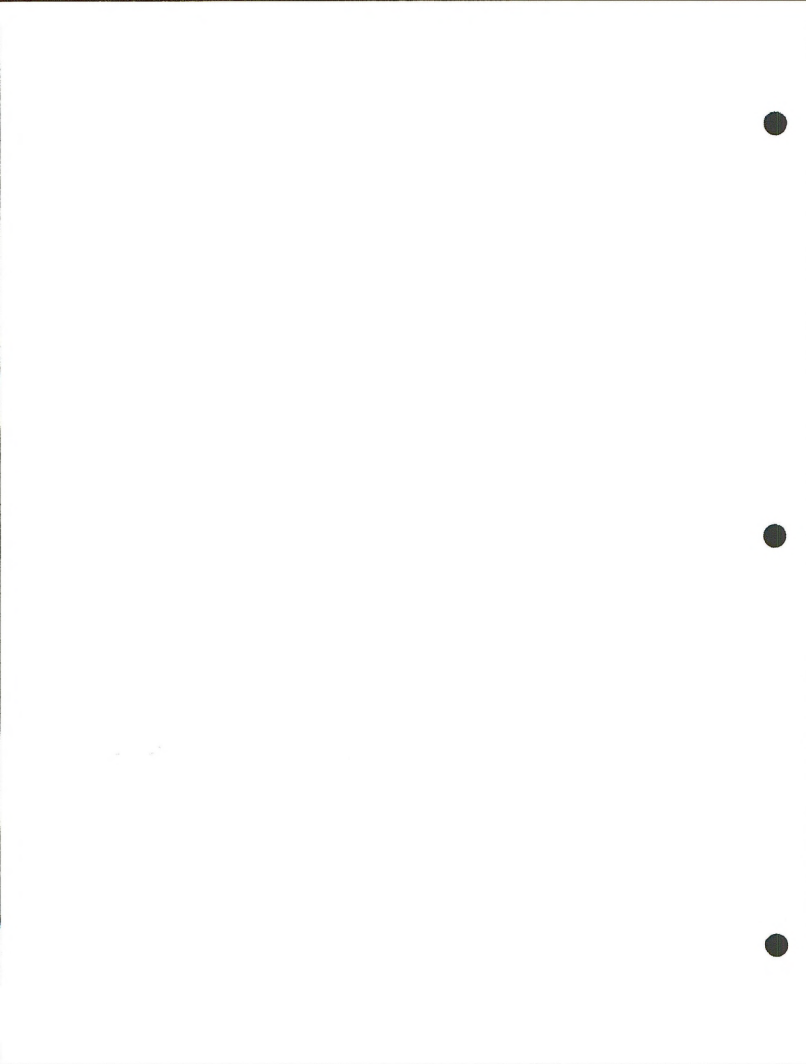
After 13 weeks of cooling and leaching with recirculated water an attempt was made to core drill the lower portion of Retort 0. At the time coring was tried the general indication was that because of channeling, additional water recirculation would not result in significant additional cooling. The retort showed immediate signs of re-ignition when the coring tools penetrated the retort. No core was retrieved and the project was halted for safety reasons. It has been estimated that several years would be required for the retort to cool sufficiently by natural means before the rubble could be safely cored.

Retort 0 was flooded, as a result of the mine dewatering pump failures, in October and November of 1982.

2.2.4.2 Retort 1

No attempt has been made to sample the rubble in Retort 1. Since the retort was flooded to a height of approximately 195 feet during the October-November 1982 mine dewatering pump failures and a considerable amount of steam was discharged up through the unflooded rubble, it is doubtful that a representative sample of undisturbed retorted rubble exists within the retort. If it does exist, it does only because of by passing through undefined channels. Subsequent groundwater inflows resulting from the unusually wet year has further altered the condition of the rubble in the flooded and unflooded portions of the retort.

Temperature data from the remaining functional thermocouples in the retort support the fact that much of the upper portion of the retort has been affected by the groundwater and steam. Some parts of the retort, however, still exhibit temperatures in the range of 190°F to 850°F.



2.3 Retort Abandonment Alternatives

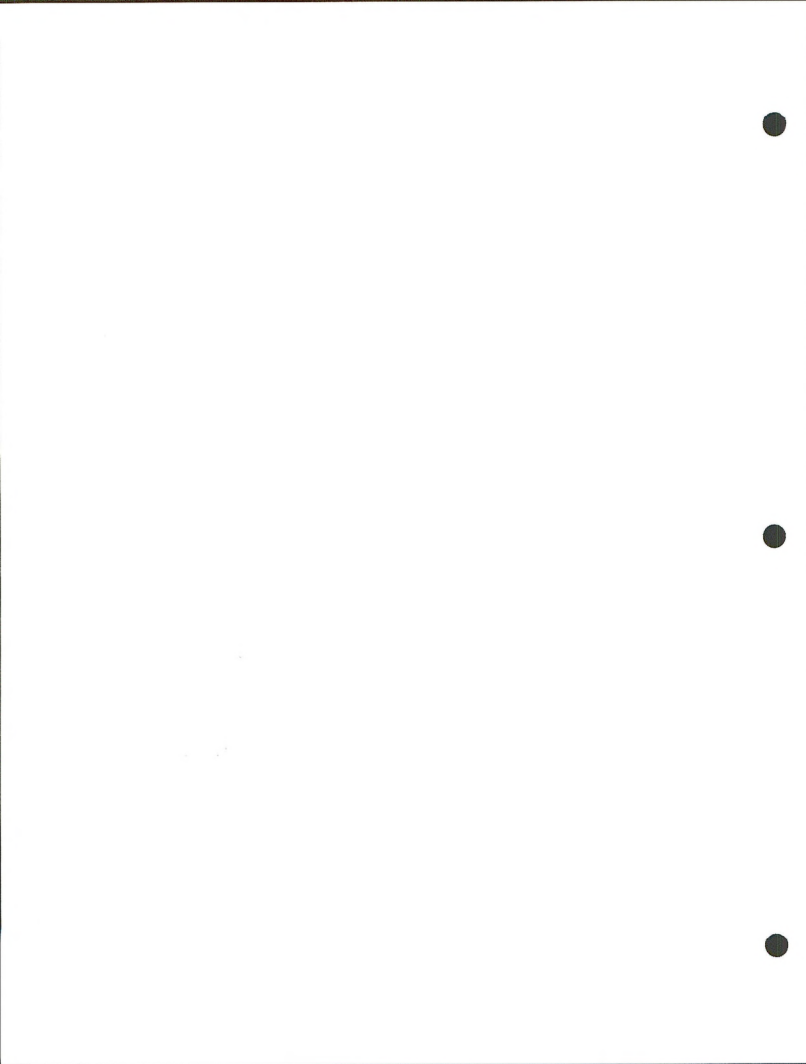
RBOSC has investigated several options for abandoning its MIS retorts. These options include:

- o Allow mine and retorts to flood and monitor groundwater for an indefinite period.
- o Leach rubble by circulating water followed by mine and retort flooding and groundwater monitoring.
- o Flood retorts, leach by recirculation, pump out leachate, flood retorts and mine and finally monitor groundwater.
- o Pump down retort, and repeat rest of preceeding item.
- o Any of the above methods with continued pumping of water from retort system at a rate great enough to maintain localized flow from aquifer into the retort.
- o Grout the retorts to render them impermeable followed by groundwater monitoring.
- o Curtain grouting around the retorts

The objective of the retort abandonment program is to cease operation and maintenance activities related to the retorts with no significant long term adverse effects to the groundwater system.

2.3.1 Description of Abandonment Alternatives

Each of the above mentioned options is briefly discussed prior to explaining the rationale used to select the proposed method for retort abandonment.



2.3.1.1 Flood and Monitor

Mine and retort flooding followed by an extended period of groundwater monitoring represents the most simplistic approach to retort abandonment. It has, however, several disadvantages which make it unacceptable to RBOSC. This approach presents the highest probability for adverse groundwater impacts in the upper aquifer with leachate coming from the retort. Because of this, the groundwater monitoring program would be extensive and virtually eternal.

2.3.1.2 Leach by Circulation Followed by Flood and Monitor

In this approach, water injected into the top of the retort would trickle down through the unflooded rubble and be either recirculated or discharged into the evaporation pond system. In either case, leaching would be ineffective because of channeling within the rubble. Once the leachate water quality indicated that leaching was no longer taking place at an acceptable rate, the retort and mine would be allowed to flood and groundwater monitoring would begin. This method would also be prone to long term release of leachate into the aquifer because of the incomplete leaching. The time required for monitoring could be extremely long and the probability of remedial action is probably great.

Another problem associated with this approach, if the leaching water is discharged into the evaporation ponds, is the possibility that the ponds capacity will be exceeded before leaching is complete. Based on construction experience, additional evaporation pond capacity is estimated to cost \$80,000 per gpm of evaporation capacity.

2.3.1.3 Flood-Leach by Circulation-Pump Down-Flood and Monitor

Under this scenario the mine and retort would be allowed to flood prior to rubble leaching. The leach water could be either recirculated or

discharged into the evaporation pond system. After the leaching phase is completed based on either water quality or some number of equivalent pore volume changes, the retort and mine would be pumped back down to remove all leachate from the retorts. The mine and retort would then be flooded and the groundwater monitoring program would be continued.

Although more effective leaching is possible when the retort leach water is discharged after one pass through the rubble rather than being recirculated, the additional evaporation pond construction impacts and cost would be prohibitive. Pond construction alone could range from 3 to 9 million dollars depending on the timing of the leach cycle.

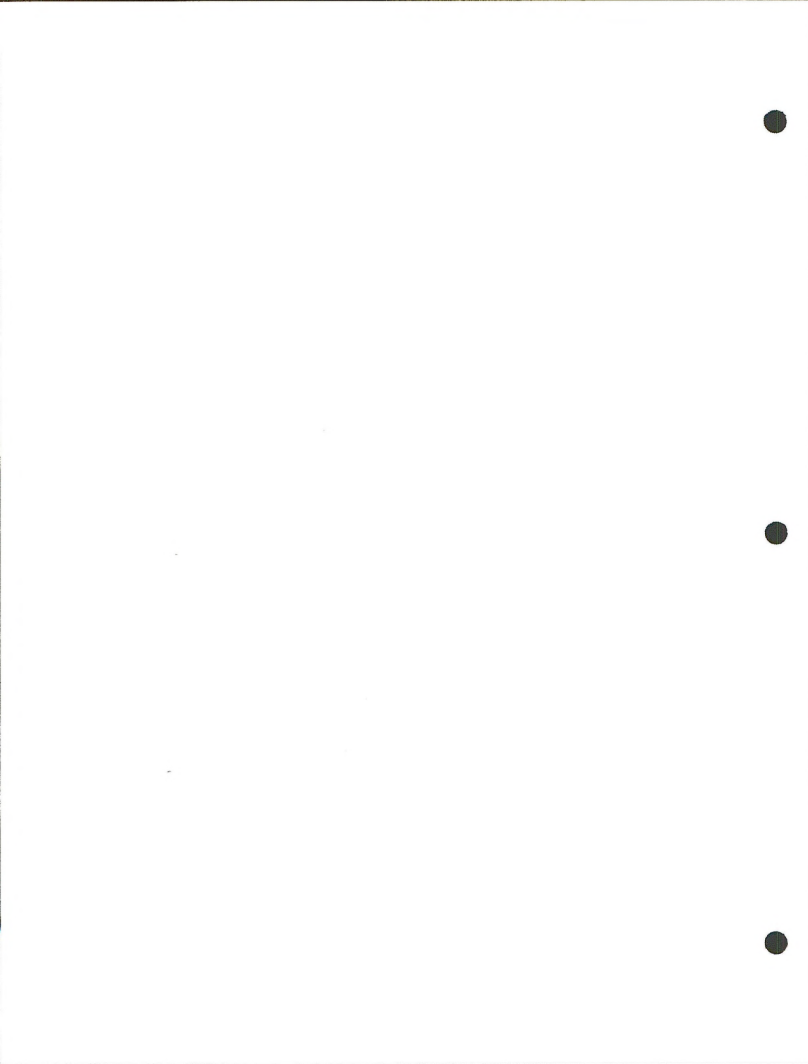
2.3.1.4 Pumpdown-Flood-Leach by Circulation-Pumpdown-Flood and Monitor

This plan is similar to the previous one (Section 2.3.1.3) with the exception that leachate currently in the system would be pumped out before starting the flood/leach cycle. More complete leaching would be expected using this approach because the retort will be flooded with groundwater rather than a mixture of leachate and groundwater. All other activities and conditions are the same as for Section 2.2.1.3.

2.3.1.5 Continuous Retort Pumping to Maintain Flow From Aquifer Into Retort

This option could be applied to each of the previous methods at any time the retort is flooded. Water would be pumped from the bottom of the retort at a rate sufficient to cause a continuous flow into the retort from the aquifer with no retort water re-entering the aquifer. This water would be discharged into the evaporation ponds.

Hydrologic modeling has shown that a pumping rate of at least 40 gpm is required to achieve this slow pattern. Additional evaporation pond construction would be required at an estimated cost of 2 million dollars.



2.3.1.6 Grout the Retort Rubble

The retort rubble would be grouted to render it impermeable. Since rubble temperature as high as 850°F still exist, Retort 1 would be cooled by flooding prior to grouting. Grouting would be done from the surface using one of several available methods.

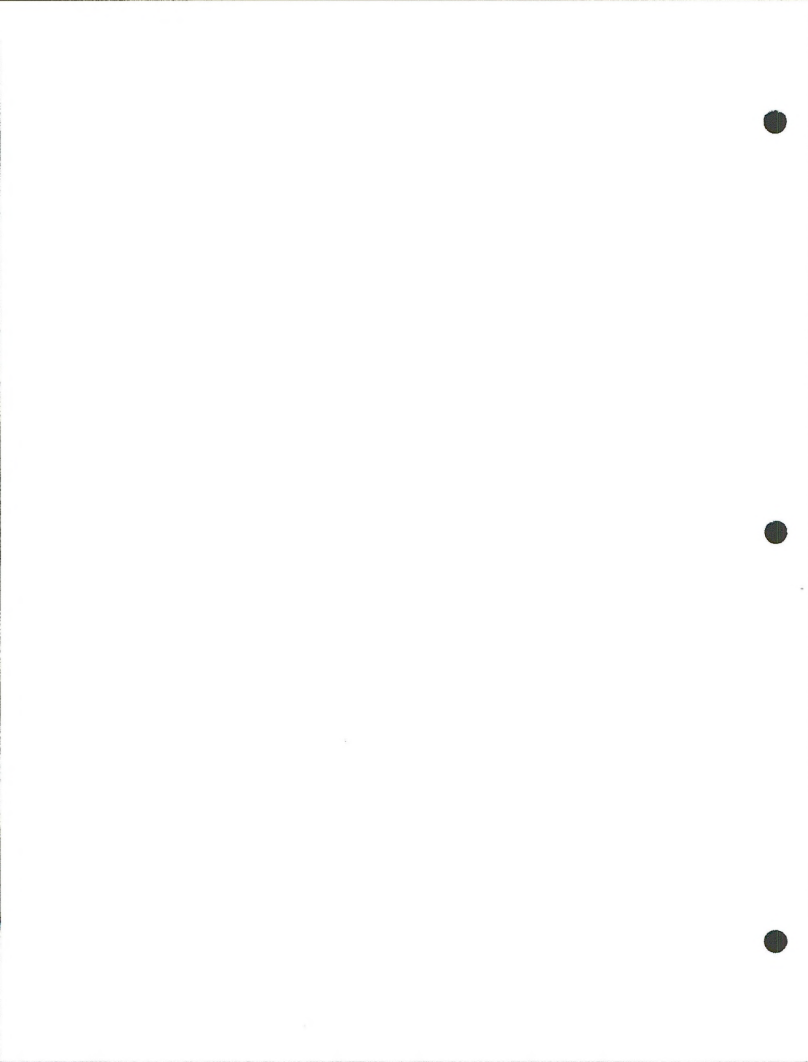
Pilot scale test work has indicated that rubble permeability can be reduced to as low as 4×10^{-6} to 7×10^{-7} cm/sec. by grouting. Rubble grouting could cost as much as 7 million dollars.

2.3.1.7 Curtain Grouting Around The Retorts

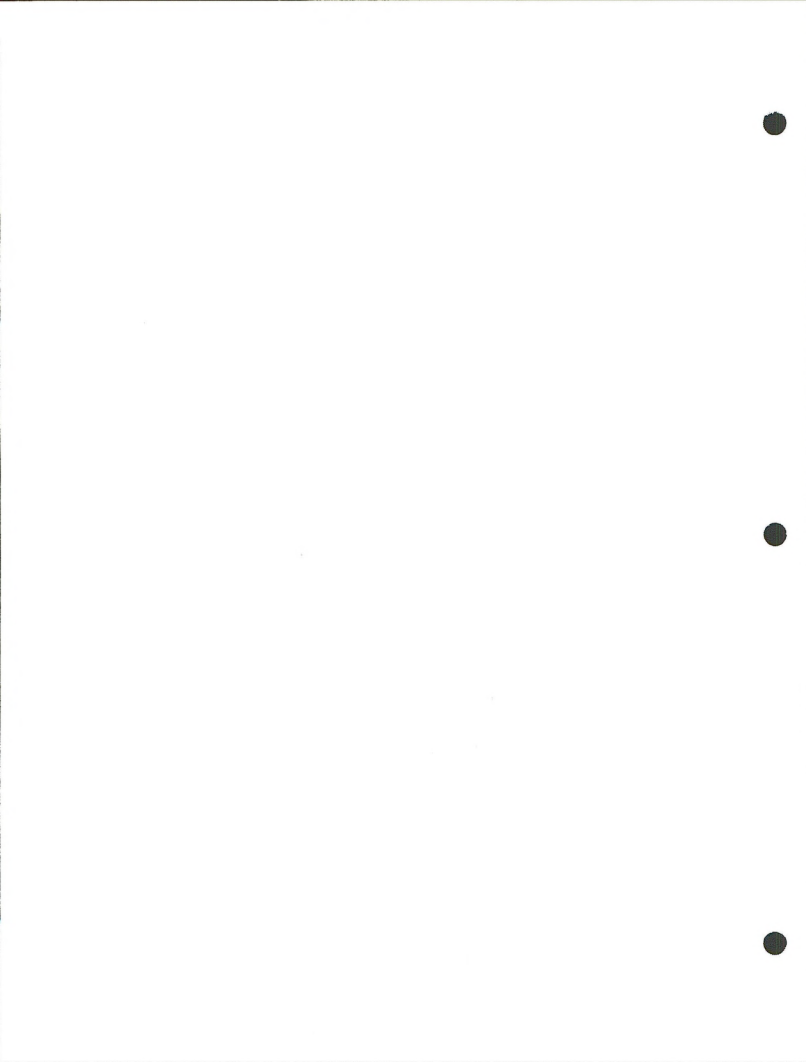
Curtain grouting from the surface would isolate the retorts from the aquifer by establishing an impermeable curtain of grout around the retorts. The probability of success using this method is low because of size and frequency of joints and fractures in the rock around the retorts. The costs would probably be much greater than for rubble grouting.

2.3.2 Selection Rationale

Based on RBOSC's experience with the retorts since the end of operation, laboratory research, and hydrologic modeling, the Pump-Flood-Leach-Pump-Monitor option described in Section 2.3.1.4 was selected for Tract C-a MIS retort abandonment. This approach provides for substantial rubble leaching prior to abandonment. Since the upper portion of the retort that is within the aquifer was well retorted, leaching is expected to be very effective (up to 80% for 7 pore volume changes based on laboratory work done by Hoel and Bunting). Hydrologic modeling indicates that groundwater flow through the retort will follow the regional hydraulic gradient with very little vertical movement (except by diffusion). This will minimize the amount of soluble material escaping from the retort. The plans for abandonment and monitoring are discussed in Sections 3 and 5 of this proposal.



The options discussed Sections 2.3.1.5, 2.3.1.6, and 2.3.1.7 are potential fallback solutions should the proposed monitoring program demonstrate that a serious groundwater problem is developing.



3.0 Retort Abandonment Plan

Retort abandonment at RBOSC's Tract C-a mine is planned to be a phased operation where the steps listed below are taken in preparation for ultimate abandonment.

- o Pump retorts down to top of collection drift.
- o Flood and cool retorts.
- o Circulate water to leach rubble.
- o Pump retorts and production collection system down to bottom of separator room.
- o Flood retorts and product collection system.
- o Commence extended monitoring programs.

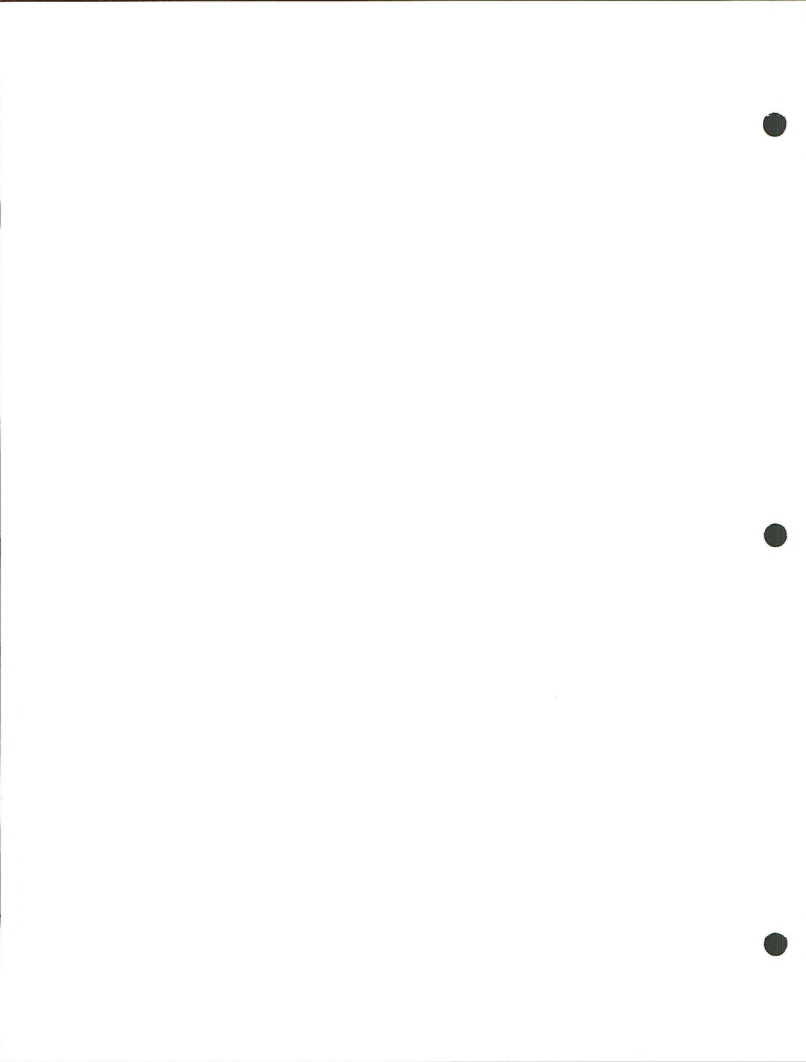
While it is RBOSC's intent to develop Tract C-a and eventually mine out the retort area, economic uncertainties dictate that the abandonment plan provide for an adequate program life. The criteria for cessation of abandonment activities is discussed in Section 5.3.

3.1 Initial Retort Pumpdown Phase

The retort system will be pumped down to the 6090 foot elevation which is the approximate roof of the product collection drift on G-level at Retort 1. This water has leached a substantial amount of the soluble material out at the lower parts of both retorts as witnessed by the conductivity of 7300 micromhos per centimeter for the water current being pumped from the retorts.

3.1.1 Pumping

Two 35-hp 65-gpm submersible pumps will be utilized to pump the retort system from the 6175 foot elevation down to the desired 6090 foot elevation. Approximately 20 days will be required to pump down the retort system. A total of 2.2 million gallons will be pumped to the evaporation



ponds with 1.1 million gallons representing the quantity within the retort system. The remaining 1.1 million gallons represents the groundwater inflow during the pumping period. The extent of mine water drawdown will be dependent upon the inflow rate relative to the maximum mine water pumping rate at that time. An effort will be made to keep the mine water level within 25 feet of the retort water level to minimize the groundwater flow into the retorts during this pumpdown phase.

3.1.2 Pond Management

The 2.2 million gallons of retort water which will be pumped into the evaporation ponds will bring the ponds to approximately 90% of capacity. Figure 2 shows the projected evaporation pond system status during the active abandonment phases. The existing spray system to enhance evaporation will be operated during the normal evaporation season.

Figure 3 shows the status of the water level in the East Pond. A spray enhancement system has been installed in the East Pond in anticipation of future water transfers.

3.1.3 Monitoring

Mine and retort water monitoring will be performed according to Monitoring-Phase I which is described in more detail in Section 5.

3.1.3.1 Daily

- o Water levels in mine and retort
- o Mine water and retort water pump flows
- o Mine and retort water quality (on site analysis)
 - specific conductance
 - pH
 - ammonia
 - fluoride

3.1.3.2 Weekly

- o Mine and retort water quality on site analysis
 - sulfide
 - phenols
 - chemical oxygen demand (COD)
 - potassium

Work will begin on the drilling and completion of four groundwater sampling and monitoring holes east of Retort 1 and one hole within Retort 1. Four existing wells around the retorts will also be completed for sampling and monitoring. (See Figure 1)

3.2 Retort Flood/Cool Phase

The retort system will be allowed to flood to the top of the Retort 1 attic which is estimated to be at approximately the 6510 foot elevation.

3.2.1 Pumping

The retort flood rate will be controlled by pumping retort water to the evaporation ponds as required to limit steam generation to a rate that can be safely handled by the surface facilities. Mine water pumping will decrease as flooding proceeds until the retorts are flooded. At that time the mine water pumps will be shut down. The flood/cool phase may take up to 4 months to complete.

3.2.2 Pond Management

Since little or no water will be put in the evaporation ponds during this time, considerable progress is expected in evaporation from the ponds. When flooding is complete the ponds could be low as 55 to 65% of capacity. These projections assume that initial flooding will take place during the evaporation season.

3.2.3 Monitoring

The mine and retort water monitoring program which will continue during the retort flood/cool cycle is discussed in more detail in Section 5 as Monitoring-Phase I.

3.2.3.1 Daily

- o Water levels in mine, retort and wells GS-D1U, D3U and MDP2CU
- o Mine and retort water pumping rates and volumes.
- o Mine and retort water quality (on-site analysis)
 - specific conductance
 - pH
 - ammonia
 - fluoride

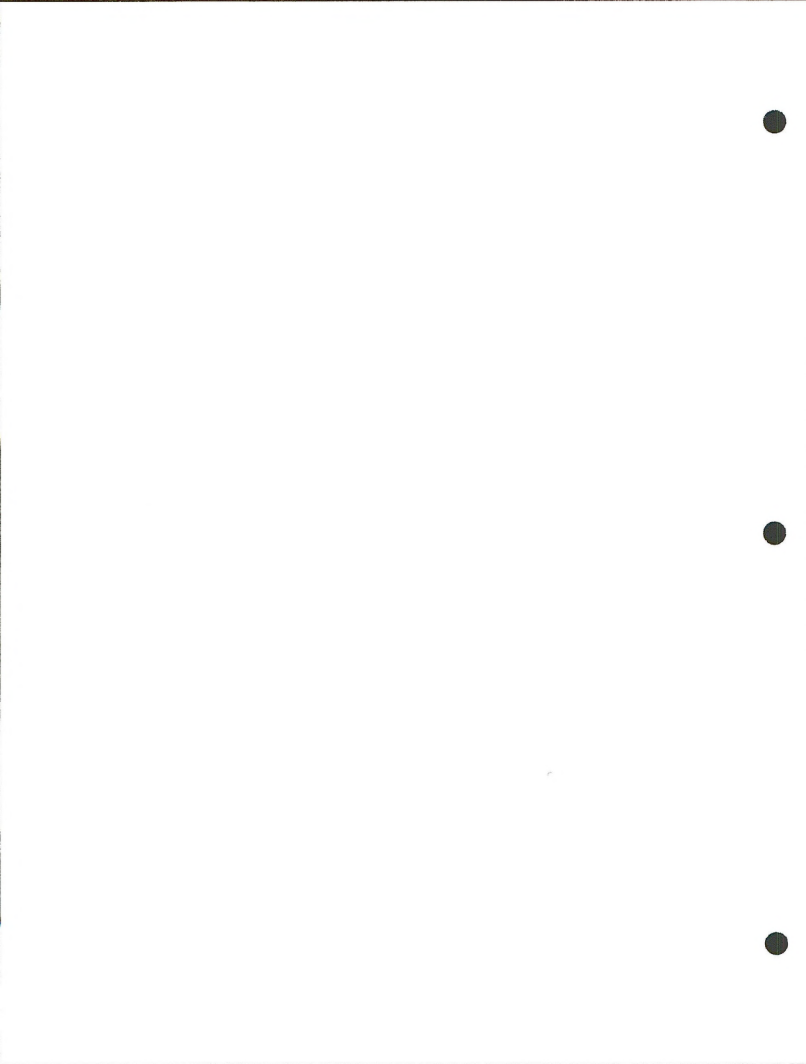
3.2.3.2 Weekly

- o Mine and retort water quality (on-site analysis)
 - sulfide
 - phenols
 - chemical oxygen demand (COD)
 - potassium

Some of the groundwater sampling/monitoring wells will be completed for the on-going monitor program.

3.3 Circulate/Leach Phase

The circulate/leach phase will consist of circulating water through Retort 1 by pumping from the bottom with the two 35-hp pumps at a rate of 60 to 120 gpm and reinjecting this water into the top of either or both retorts. The time required for this phase is not defined, but 1 pore volume change requires about 25 days. For planning purposes 7 pore volumes were assumed to be adequate. Research work by Hoel and Bunting has shown up to 80% reduction in TDS after leaching for 7 pore volumes. Specific



conductance will be checked daily and other water quality parameters such as potassium and COD will be checked weekly to determine the effectiveness of the leaching effort. The leaching time required may be altered based on the rate of change in the retort water specific conductance or these other water quality parameters.

The slow rate of circulation in the flooded state should provide for effective leaching of the rubble since channeling will not be likely.

3.3.1 Pumping

Either or both of the 35-hp pumps will be used to circulate water through the retorts. It may be necessary to discharge a limited amount of retort water to the evaporation ponds. No mine water is planned to be pumped during this phase.

3.3.2 Pond Management

Since some retort water may be discharged during this phase, an allowance has been made to accommodate it in the pond management program. The ponds could be as much as 85% full at the end of this phase.

3.3.3 Monitoring

The retort and mine water monitoring program will continue with the addition of some groundwater well sampling as discussed in the Monitoring-Phase I detailed description of Section 5.

3.3.3.1 Daily

- o Water levels in the mine, retort, and wells GS-D1U, D3U and MDP2CU
- o Mine and retort water pumping rates and volumes.
- o Mine and retort water quality (on-site analysis)

- specific conductance
- pH
- ammonia
- fluoride

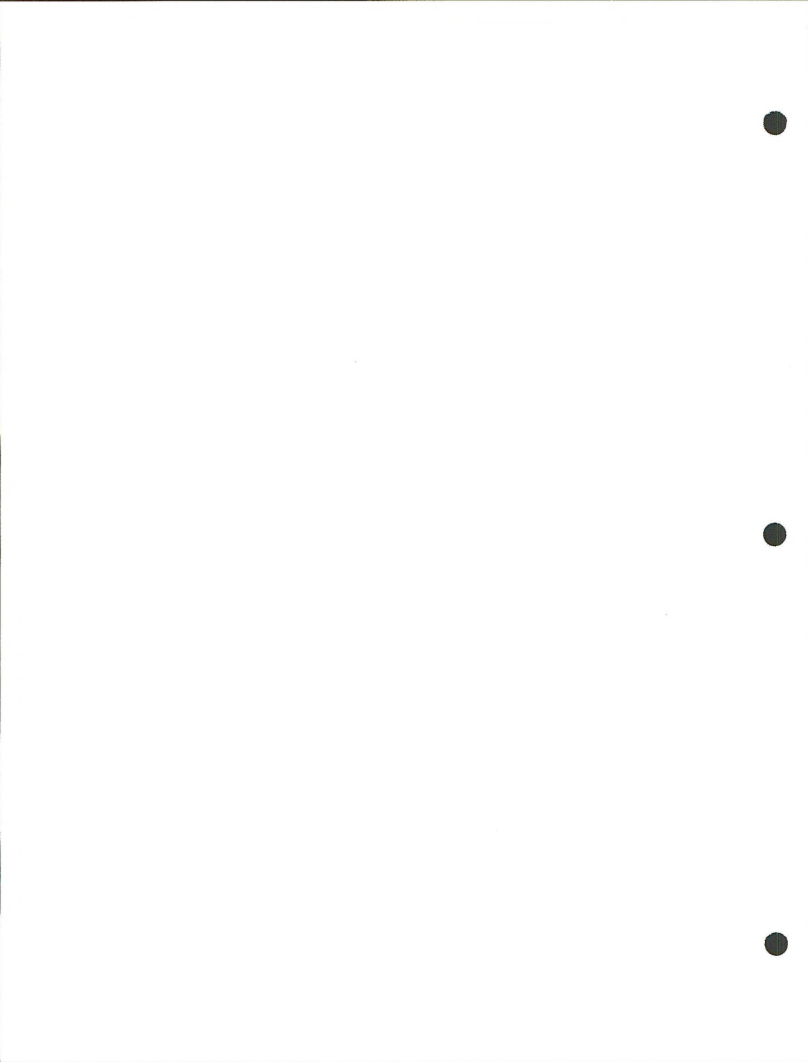
3.3.3.2 Weekly

- o Mine and retort water quality (on-site analysis)
 - sulfide
 - phenols
 - chemical oxygen demand (COD)
 - potassium
- o Wells GS-D1U, D3U and MDP2CU water quality (on-site analysis)
 - specific conductance
 - pH
 - ammonia
 - fluoride
 - sulfide
 - chemical oxygen demand (COD)
 - potassium

All planned exterior sampling/monitoring wells will be completed by the end at the circulate/leach phase of retort abandonment.

3.4 Total Retort Pumpdown Phase

Upon completion of the leach phase the retort system will be completely pumped down to the 6070 foot level. This will remove all water from the retorts, product collection drift and the separator room. It will be necessary to partially pump down the mine water to reduce the hydraulic head on the G-level bulkheads which separate the mine from the retorts and to minimize water flow into the retorts.



3.4.1 Pumping

Both 35-hp pumps will be used to pump out the retort system. Approximately three months will be needed to complete the retort pumping. About 9.8 million gallons will be pumped with 7.2 million gallons coming from the retort system and the remaining 2.6 million gallons being inflow water during the pumping time.

The mine will be pumped down to the 6150 foot level during the total retort pumpdown phase. This water will be reinjected into the upper aquifer.

3.4.2 Pond Management

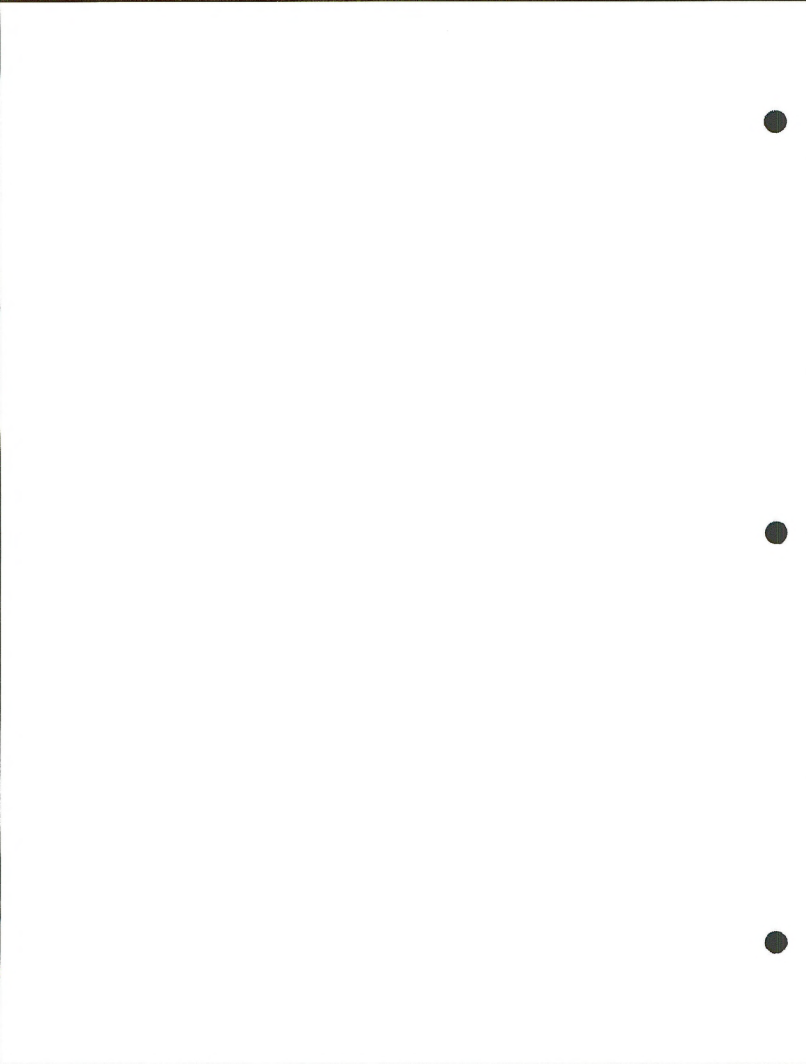
It will be necessary to transfer at least 3 million gallons of retort water to the East Pond during the total retort pumpdown phase. Figure 2 shows that the evaporation ponds capacity will be exceeded if the East Pond is not used. No additional discharge to the evaporation ponds is contemplated after the total retort pumpdown is completed.

3.4.3 Monitoring

During final retort pump down monitoring will continue with no major changes in the Monitoring-Phase I criteria.

3.4.3.1 Daily

- o Water levels in the mine, retort, wells GS-D1U, D3U and MDP2CU, and the new sampling/monitoring wells
- o Mine and retort water pumping rates and volumes.
- o Mine and retort water quality (on-site analysis).
 - specific conductance
 - pH
 - ammonia
 - fluoride



3.4.3.2 Weekly

- o Mine and retort water quality (on-site analysis)
 - sulfide
 - phenols
 - chemical oxygen demand (COD)
 - potassium

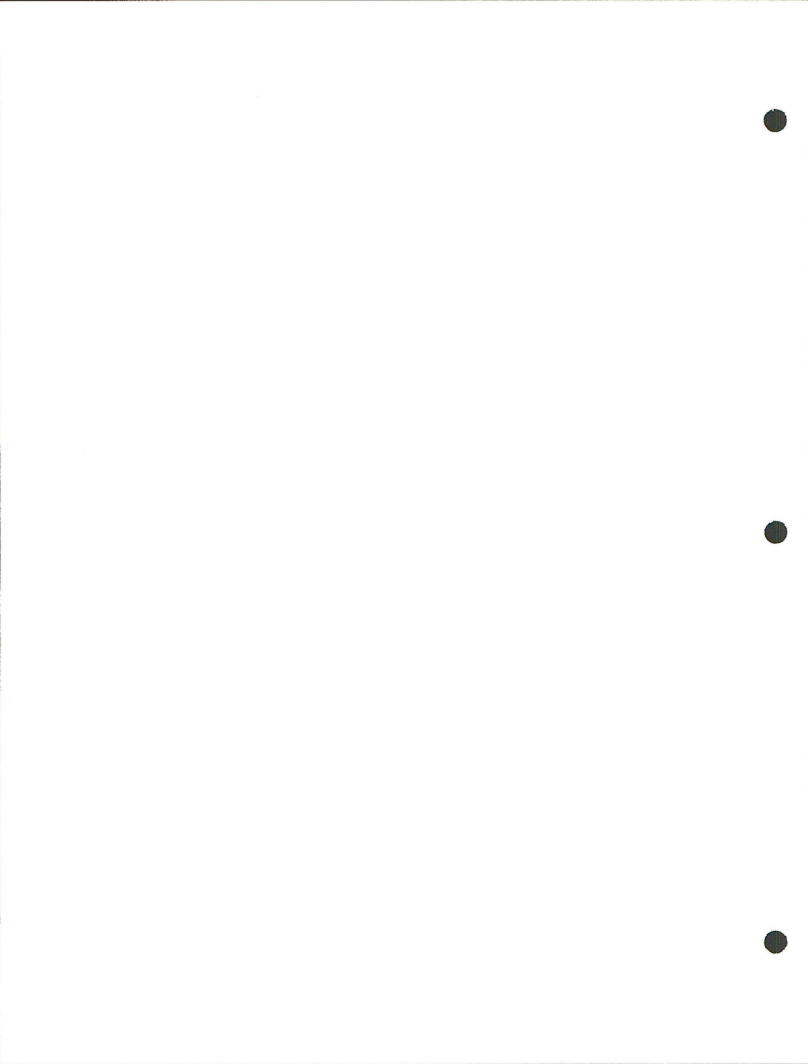
- o Wells GS-D1U, D3U, MDP2CU, and the new sampling/monitoring wells (including the retort well)
 - specific conductance
 - pH
 - ammonia
 - fluoride
 - sulfide
 - phenols
 - chemical oxygen demand (COD)
 - potassium

3.5 Final Retort Flooding Phase

The retorts and mine will be allowed to completely flood and extended monitoring program will be instituted.

3.5.1 Flooding

The mine and retorts will be allowed to completely flood. Retort flooding will be expedited by injecting mine water into the top of Retort 1. All pumps will then be shut down and the retorts will be in an abandoned status.



3.5.2 Pond Management

The evaporation ponds and the East Pond will be placed in a standby status and will be maintained until such time that they are used again or abandoned.

3.5.3 Monitoring

Monitoring will continue during final retort flooding with a change in procedures to the Monitoring-Phase II criteria.

3.5.3.1 Daily

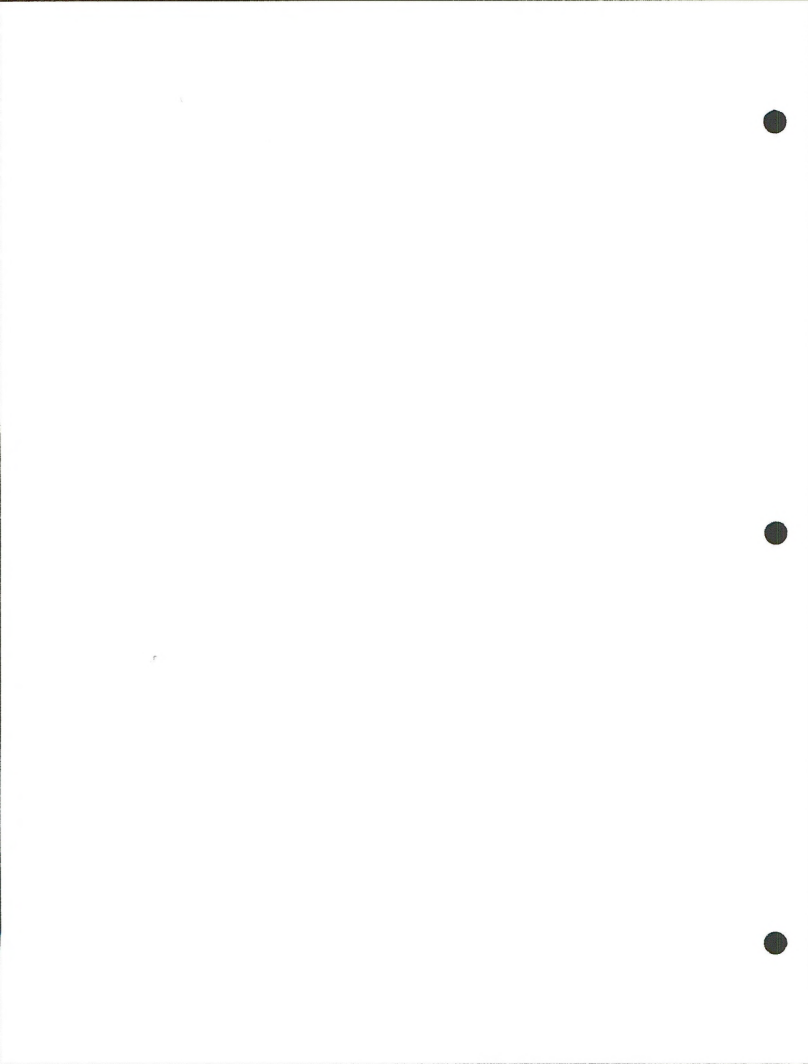
- o Water levels in the mine, retorts, wells GS-D1U, D3U and MDP2CU, and the new sampling/monitoring wells
- o Mine water pumping rate and volume.

3.5.3.2 Weekly

- o Wells GS-D1U, D3U, MDP2CU, D5U and the new sampling/monitoring wells (including the retort well)
 - specific conductance
 - pH
 - ammonia
 - fluoride
 - sulfide
 - phenols
 - chemical oxygen demand (COD)
 - potassium

3.5.3.3 Monthly

- o BWQ sample collected from the mine, retort well, 4 new monitor wells, GS-1DU, D3U, MDP2CU, and D5U.



3.6 Extended Monitoring

Once the retort and mine have been flooded, the monitoring program Phase II will continue as described in Section 5. The rationale for on-going monitoring and decision point responses are also discussed as Phases III and IV in Section 5.

3.6.1 Extended Monitoring - Phase II

Phase II monitoring begins once the mine and retort have been flooded following the total retort pumpdown phase.

3.6.1.1 Daily

- o Water levels in the mine and retort

3.6.1.2 Weekly

- o Water levels in wells GS-D1U, D3U, MDP2CU, and the new sampling/monitoring wells.
- o Water quality with on-site analysis from the mine, retort well, and the new sampling/monitoring wells
 - specific conductance
 - pH
 - ammonia
 - fluoride
 - sulfide
 - phenols
 - chemical oxygen demand (COD)
 - potassium



3.6.1.3 Monthly

- o Basic Water Quality (BWQ) samples will be collected from the mine, retort well, and the GS-D1U, D3U, MDP2CU, and new sampling/monitoring wells and sent to an outside lab for analysis.

3.6.1.4 Termination of Phase II Monitoring

Phase II will end and Phase III will be initiated when the following are observed in any of the 4 new monitor wells in four consecutive weekly samples:

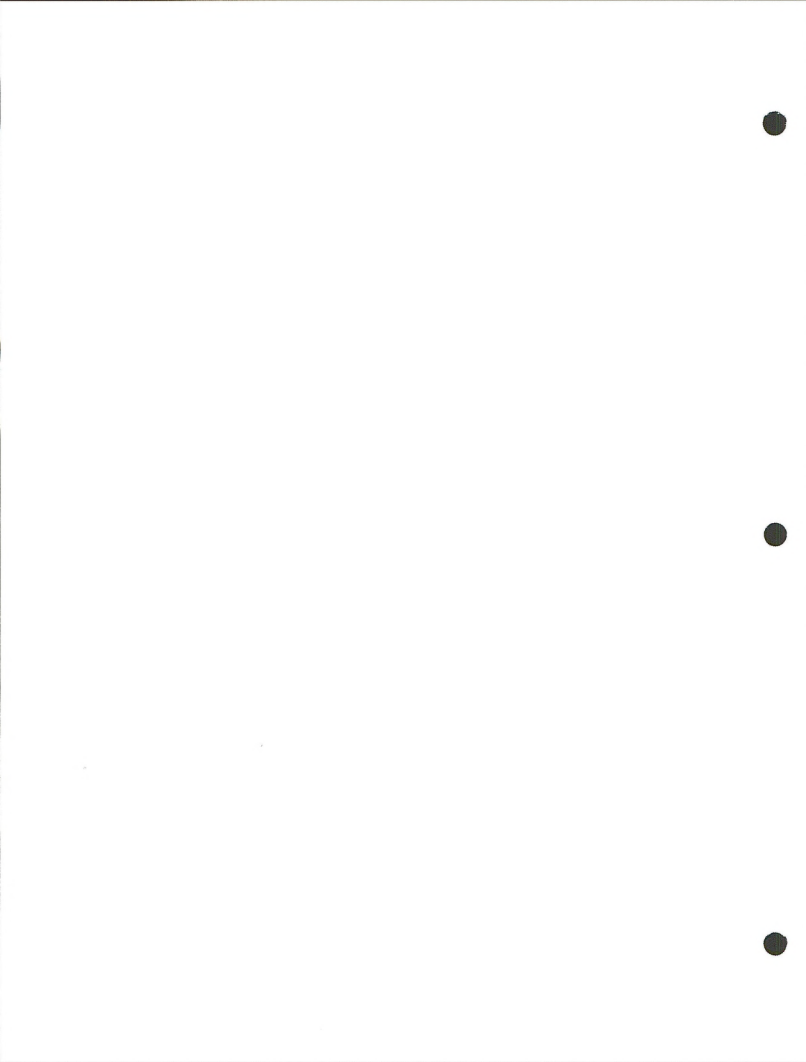
- o potassium greater than 10 mg/l
- o fluoride greater than 6 mg/l
- o specific conductance greater than 5000 micromhos/cm
- o sulfide greater than 20 mg/l

3.6.2 Phase III

Phase III is initiated in response to water quality changes in the four new monitor wells that indicates retort leachate moving out into the upper aquifer. A more detailed description of the transition from Phase II to Phase III is discussed in Section 5.

3.6.2.1 Monitoring Activities

- o Collect initial BWQ, TWQ and priority pollutant sample from mine, retort well, 4 new monitor wells, GS-D1U, D3U, MDP2CU, D5U, repeat semi-annually for priority pollutants and trace constituents observed in measureable quantities.
- o Twice per month run BWQ from mine, retort well, 4 new monitor wells
- o Twice per week on-site measurement of quality of mine water, retort well, 4 new monitor wells (8 parameters)



- o Weekly water level measurement in mine, retort well, 4 new monitor wells, GS-D1U, D3U, MDP2CU, D5U

3.6.3 Impact Response

Impact Response-Action and related monitoring. Phase III observation in near-retort wells of potentially deleterious impacts to the upper aquifer will call for response by RBOSC. This response may include pumping of the retort directly to establish a small cone of depression with flow toward the retort. In this manner, contaminated water will be drawn back into the retort and discharged to evaporation ponds. Another response option is seal the retort from the aquifer by either grouting the rubble or establishing a grout curtain around the retort.

3.6.3.1 Response Triggers

This impact response will be triggered by the following monitoring observations:

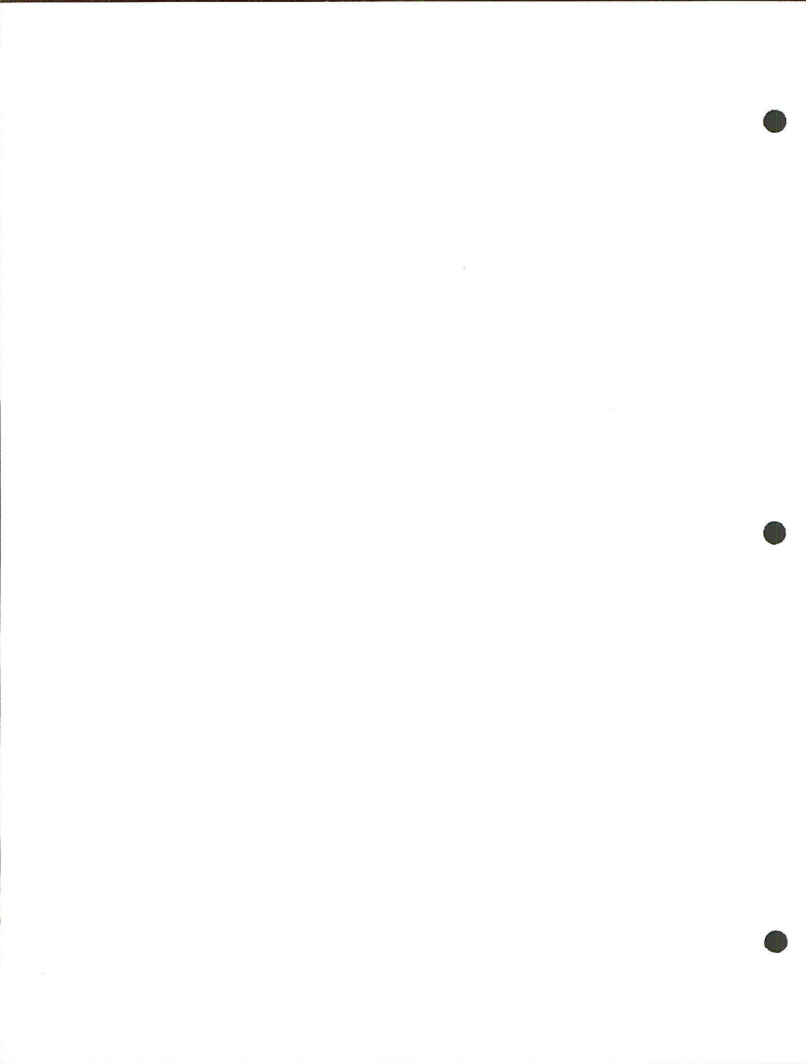
- o Observations in near-retort wells of concentrations exceeding the following:

-TDS	12480 mg/l
-Boron	15.2 mg/l
-Molybdenum	1.5 mg/l
-Lithium	11.2 mg/l

These concentrations near the retort indicate a potential to exceed selected criteria at the tract boundary. (See Section 5)

These criteria are as follows (data from California Cooperative Extension, 1973):

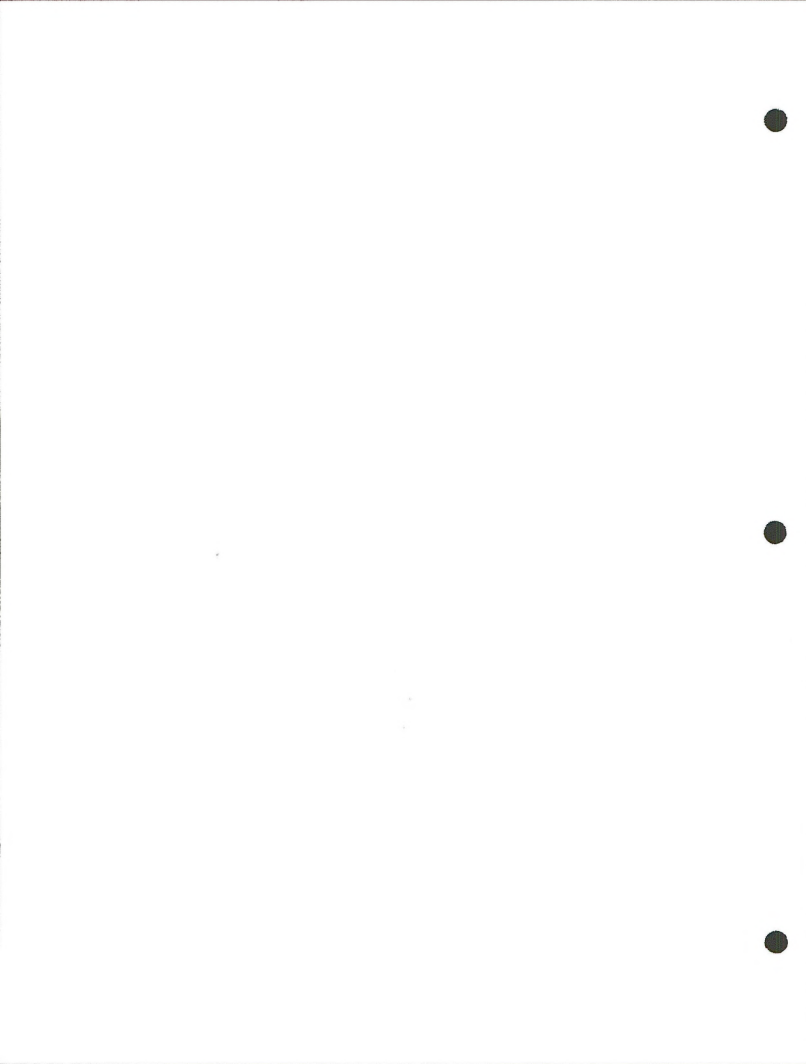
- Boron - greater than 5 mg/l (estimated tolerance of alfalfa and also estimated toxic level to livestock)
- Molybdenum - greater than 0.5 mg/l (estimates toxic level for livestock)



- Lithium - greater than 2.5 mg/l (recommended maximum concentration in irrigation water)
- TDS - up to 5000 mg/l (considered satisfactory for livestock)

3.7 Phase IV

Monitoring will be terminated when abandonment has been declared complete by the Oil Shale Office. Phase III monitoring data and projections using the calibrated Law Engineering model will be used to define the extent to expected impact. If an impact response is not anticipated, then abandonment will be complete. If Phase III monitoring after two years does not indicate a need for impact response and the final six months of this Phase III monitoring does not show an increasing trend in BWQ constituents, then abandonment will be considered complete and monitoring will be terminated.



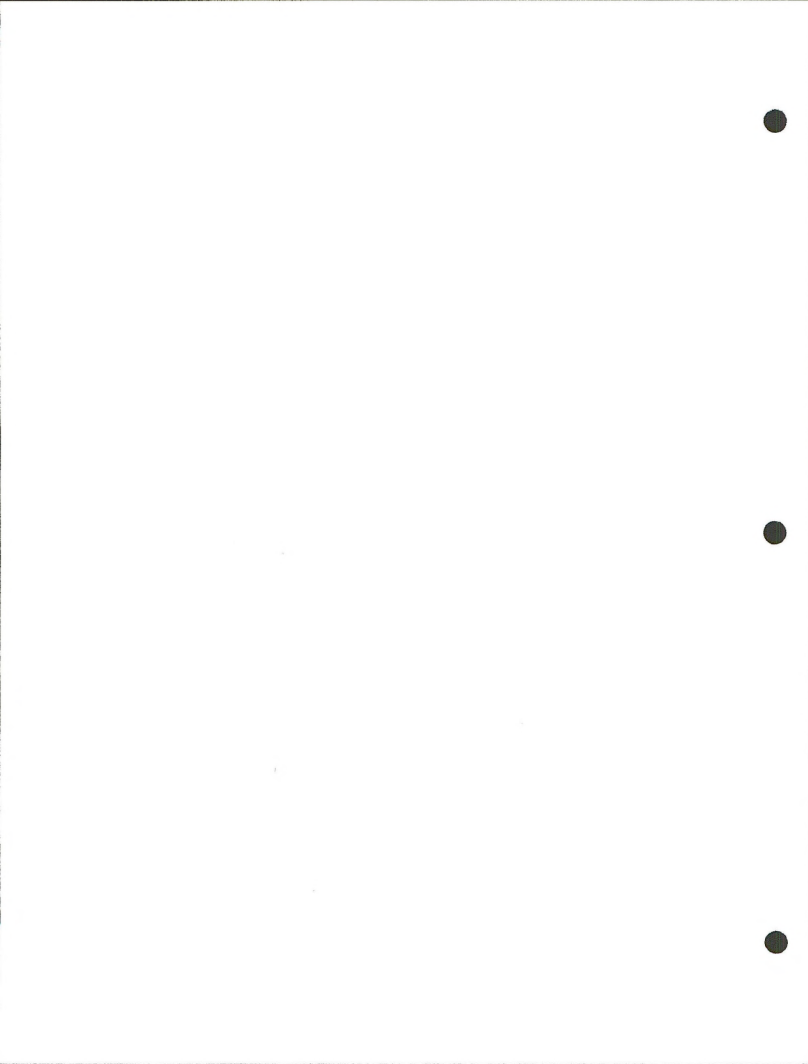
4.0 Retort Stability

Rock mechanics monitoring during retorting indicated that the roof of Retort 1 caved and eventually stabilized at about 30 to 40 feet above the original roof level. Due to bulking of the caved material and the relatively small cross sectional retort area involved, no additional caving and certainly no surface subsidence is anticipated. Survey measurements, which were made at 6 month intervals during 1980 through 1982 show no evidence of surface subsidence in or around the retort area. The subsidence monitoring program was discontinued in 1982.

At the end of the Retort burn, the caved roof zone at the east side of the retort reached about 40 feet above the highest point in the pre-ignition retort roof. The cone or arch of ultimate failure may extend to and stabilize another 30 feet higher.

The vertically reduced stress zone above a single opening is generally considered to extend one to two opening spans above the opening boundary. The conclusion can be stated that the vertical effects of retorting on the roof were confined to the vertically reduced stress zone (60-120 feet) over the initial retort boundary.

The ramifications of rubble settling due to leaching, which would be a concern in a commercial MIS operation, are not significant in the case of RBOSC's MDP retort abandonment program.



5.0 Monitoring Plan For Abandonment

The MIS retort abandonment program described in the preceding sections was designed to minimize the environmental risk associated with this activity. The monitoring plan has been developed to track the progress of abandonment and to measure the effects of abandonment on the upper aquifer on Tract C-a. Because of the small size and isolated location of these experimental MIS retorts, these effects are expected to be localized and minimal. The very limited use of upper aquifer water further minimizes the potential health and environmental effects of the proposed action. These conclusions are supported by modeling studies and by data collected to date on the partially-flooded MIS retorts.

5.1 Impacts of MIS Retort Abandonment

5.1.1 General Observations

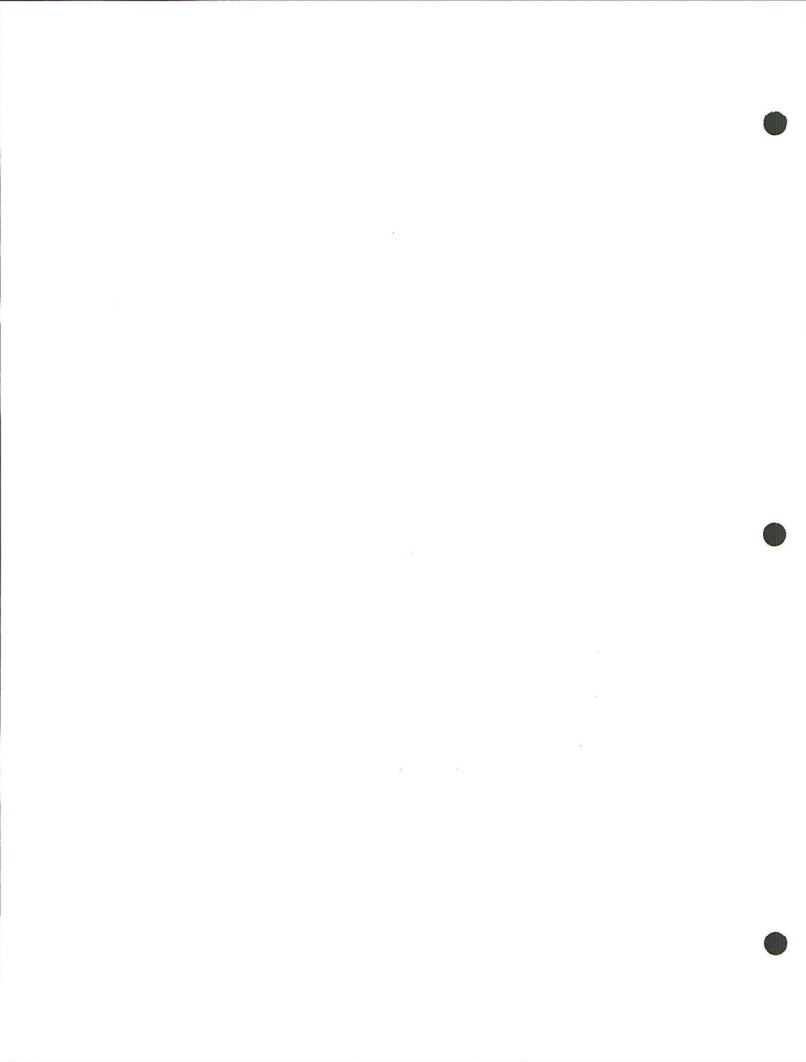
- o Retort leachate concentrations may be expected to be high in the immediate vicinity (within a few thousand feet) of Retort One. This is inferred from modeling studies which do not include consideration of the benefits of pre-leaching of the retort.
- o However modeling studies (e.g. Law Engineering, 1981; E.T. Haung (simulation using USGS regional model)) indicate that the long-term regional effects of retort abandonment are expected to be minimal. This conclusion is supported by Ramirez and Abedi (1979) in their study for the Colorado Water Quality Control Commission. Peterson et. al. (1982) concluded that ground-water quality impacts of in situ processing "may be less than previously believed". Solubility controls by major ions may, with some exceptions, mitigate trace metal effects.

- o Data on the quality of post-burn drainage from Tract C-a retorts indicates a fairly rapid decay in leachate concentration (increasing quality) with time.
- o Long range effects, if measurable, will be slow. For example, modeling work by RBOSC reported by Ramirez and Abedi (1979) estimated that at a distance of 3 miles from abandoned retorts, the excess TDS was shown to rise from 0 to 10 mg/l in 35 years; at 7 miles the time frame for a 10 mg/l rise was estimated to be 90 years.
- o Present groundwater use near Tract C-a is limited to Rio Blanco operations.

The following summary of research on in situ retort abandonment impacts is taken from "Leaching of Oil Shale Solid Wastes: A Critical Review (Fox, 1982). References cited here are listed in Fox (1982).

The impact of in situ spent shale leachates has been investigated in a number of modeling studies (Mehran et al., 1980; Robson and Saulnier, 1981; Brown et al., 1977) and laboratory studies (Stollenwerk, 1980; U.S. DOE, 1980; Jackson et al., 1975; Peterson et al., 1981; Wagner et al., 1981; Amy, 1978; Amy and Thomas, 1977; Amy et al., 1980; Hall, 1982; Fox, 1982; Bethea et al., 1981; Kuo et al., 1979; Parker et al., 1980; Krause et al., 1980; Leenheer and Stuber, 1977).

Early studies (Jackson et al., 1975; Amy, 1978; Parker et al., 1977) and analyses based on them (Fox, 1978; Fox, 1980) suggested that high concentrations of total dissolved solids (TDS) and certain trace elements would be leached from in situ spent shales and transported in local aquifers, posing a health and economic problem to local water users in the Upper Colorado River Basin. These early conclusions were based on leaching studies conducted on simulated spent shales (Amy, 1978; Jackson et al., 1975; Parker et al., 1977) that are now known to be chemically different



from field samples (Smith et al., 1978; Burnham et al., 1978; Park et al., 1979; Wagner et al., 1981) and on unrealistic laboratory simulations of field conditions in which distilled water and very small particle sizes were used.

Recent studies at Los Alamos National Laboratory (LANL) (Peterson et al., 1980; Wagner et al., 1981) demonstrate that the impact of in situ leaching on groundwater quality may be less significant than previously believed. These studies confirm earlier work by Park et al. (1979) and Kuo et al. (1979) that high temperatures (800-1000 C) and long residence times (days to years) at elevated temperatures common during and after in situ retorting, decrease the solubility of most elements studied by about an order of magnitude. Among the important trace elements, only vanadium showed increased solubility at elevated temperatures. These studies also indicate that secondary solubility controls may actually improve groundwater quality by providing anions such as sulfate or carbonate which precipitate many toxic metals. The LANL work suggests that of the elements studied, only V, Se, and Pb may pose an environmental hazard.

Characterization, field migration, and mechanistic studies have been conducted on in situ spent shale leachates. The characterization studies have focused on elemental analyses of leachates from Occidental (Wagner et al., 1981; Kuo et al., 1979; U.S. DOE, 1980) and Geokinetics (Krause et al., 1980) retorts. No data are available on organic, or organometallic species in field leachates. However, two studies have reported organic analyses for simulated in situ samples from the Lawrence Livermore National Laboratory (LLNL) and Laramie Energy Technology Center (LETC) retorts (Hall, 1982, 1982; Amy, 1978). These studies reveal that in situ leachates have a pH of 7 to 11 and that organic nitrogen, phenols, V, Pb, and Se may occur at environmentally significant concentrations.

The field studies (Jackson et al., 1975; Stover, 1981; Sharrer, 1981; Virgona et al., 1979) have monitored the effect of actual field in situ experiments on local groundwater quality. In these studies, the retorting

site is surrounded by a series of monitoring wells which are periodically sampled over long periods of time. Much of this work is too new to yield any significant conclusions.

The work by Jackson et al. (1975) and Virgona et al. (1979) was conducted at LETC's true in situ experimental site at Rock Springs, Wyoming. Much of this work was inconclusive due to analytical problems, inadequate information on local geohydrology, and the absence of an analytical framework to evaluate the data. There were no consistent changes in quality, except that carbonate, bicarbonate, TOC, and B increased in most wells. Boron concentration remained high following retorting.

Industry self monitoring programs are in progress at Occidental's Logan Wash site (Stover, 1981) and at Geokinetics' Seep Ridge site (Sharrer, 1981). Meglen and Erickson (1981) have used pattern recognition techniques to analyze water quality data from the Occidental site. They found that few water quality changes could be attributed to the transport of leachates from the retorts, and the only statistically significant changes that they reported were increased Li concentrations at one stream site, increased B, K, and alkalinity at two satellite wells close to the retorts, and increased Mg, SO_4 , and K at one distant satellite well.

The mechanistic studies have investigated the effect of various retorting and leaching variables on leachate composition. Several studies have considered the effect on leachate quality of retorting conditions, including temperature, time at temperature, and inlet gas composition (Park et al., 1979; Bethea et al., 1981; Wagner et al., 1981). These studies employ small laboratory reactors in which conditions can be carefully controlled. Other investigators (Amy, 1978; Amy and Thomas, 1977; Amy et al., 1980) have used samples from larger, simulated in situ retorts to study the effect of retorting on leachate quality.

Other mechanistic studies have focused on thermodynamic and kinetic leaching variables. A wide range of variables and conditions has been



studied, including: (1) leach water temperature (Amy, 1978; Bethea et al., 1981); (2) water quality (Amy, 1978; Bethea et al., 1981; Wagner et al., 1981); (3) particle size (Amy, 1978; Jackson et al., 1975); (4) leaching atmosphere (U.S. DOE, 1980); (5) wet-dry cycles (Wagner et al., 1981); (6) shale-water contact time (Amy, 1978; Wagner et al., 1981); (7) groundwater flow velocity (Hall, 1982); (8) pore volume (Hall, 1982; U.S. DOE, 1980; Stollenwerk, 1980); (9) and solid-to-liquid ratio (Amy, 1978).

Several investigators have developed water and solute transport models of in situ retorts and/or surrounding aquifers. Water movement through an abandoned in situ retort has been modeled by Brown et al. (1977); by Mehran et al. (1980); and by Robson and Saulnier (1981). These studies conclude that for commercial scale abandonment (e.g. several hundred retorts) regional impacts from leaching may be significant. These studies reveal that saturated-unsaturated flow and fracture systems should be simulated in future work. All of these studies were limited by the availability of adequate laboratory and field data. Others have or are developing solute transport models of the retort and aquifer systems. Hall (1982) and Amy (1978) have developed mass-transfer models for spent shale TOC, and new work at Denver Research Institute will attempt to simulate other chemical species.

5.1.2 Tract C-a MIS Retort Leachate Impacts

Since the MIS retorts on Tract C-a were flooded in late 1982, an extensive monitoring program has been conducted to characterize the leachates produced. This monitoring includes 42 inorganic constituents (general water quality measures such as pH and conductivity, the major anions and cations, and 24 trace metals). In addition, data on reduced sulfur species, dissolved organic carbon and trace organics has been collected. These data were examined from a toxicological standpoint and where possible compared to water quality standards. Comparison was also made with the ambient water quality to evaluate the potential impacts of abandonment and to select appropriate constituents for monitoring.

Data on inorganic constituents, trace metals and trace organics in Tract C-a MIS retort leachate are presented in Section 5.5. Although these data were used to examine potential impacts of abandonment, this impact analysis may be conservative since the proposed recirculation/leaching program will remove a significant portion of the soluble material in the retorts prior to flooding and direct interaction with the upper aquifer.

State water quality standards have been established for agricultural and domestic uses and for protection of aquatic biota. As is normal, there is a significant "safety factor" built into these numeric standards. Comparison of retort leachate water quality with Colorado water quality standards shows that the leachate exceeds most of the standards. However, as shown in Section 5.4, the ambient upper aquifer water quality will also at times exceed these standards.

Thus a more appropriate measure of impact is comparison of leachate water quality with that of the upper aquifer and area streams (Table 5). The recent retort leachate data provides a conservative measure of what may be expected to leach from Retort 1 into the upper aquifer. Lower Yellow Creek is the nearest downstream continuous surface stream which may ultimately (perhaps decades after abandonment) be affected by retort leachates. Chemical analyses for leachate water for the period since November 1982 are presented in Section 5.5.

The data shown in Table 5 indicate that certain constituents (such as potassium, chloride, sulfide and ammonia) would be expected to increase very significantly relative to ambient conditions in the upper aquifer. Other constituents would be expected to show only moderate increases or possibly some decrease. Most of the impacts of abandonment are expected to be associated with increases in major inorganic ions and a few selected trace constituents. As shown in Section 5.5, most of the trace constituents in the retort leachate are at or below analytical detection



Table 5

Comparison of Yellow Creek, Upper Aquifer and Retort Water Quality

Constituents	(a) Max Observed in Lower Yellow Ck 1973-1982	(b) 95% Confidence Level, C-a Upper Aquifer 1974-1982	(c) Max. Observed in Retort Water, 11/82-8/83	c/a	c/b
ec	5200	2524	7650	1.47	3.03
TDS	3070	2432	5856	1.91	2.41
pH	9.1	8.9	8.8	.97	.99
alkalinity	1920	749	834	.43	1.11
Ca	130	145	160	1.23	1.10
Mg	140	150	88	.63	.57
K	8.6	4.5	1300	151.16	288.89
Na	1200	350	960	.80	2.74
Cl	260	40	472	1.82	11.80
NO ₃ -N	2.7	1.3	.52	.19	.40
SO ₄	750	846	3243	4.32	3.83
Sulfide	0.6	11.7	201	335.00	17.2
F	3.0	3.6	10.1	3.37	2.81
NH ₃ -N	.27	1.8	54	200.00	30.00
PO ₄	1.80	.3	.06	.03	.20
B	0.87	1.95	3.75	4.31	1.92
SiO ₂	20.0	48.8	28.0	1.40	.57
DOC	43	28.6	78	1.81	2.73
Li	.180	0.25	3.4	18.89	13.60
Pb	.013	<1.0	.01	.77	---
Mo	.080	<.20	.8	10.00	4.00
Ni	<.050	<.05	<.05	---	---
Se	.005	<.01	.02	4.00	2.00
As	.010	<.02	.02	2.00	1.00
V	<.050	<.5	<.1	---	---
Hg	.9 ppb	.3 ppb	.4 ppb	0.44	1.33

levels. Thus the impact from most of the trace constituents sampled is expected to be negligible.

Moderate increases in dissolved organic carbon in the upper aquifer may be expected from abandonment (Table 5). A large number of trace organics will be present in any leachate from MIS retorts. To examine these a GC/MS analysis was performed. In addition, the priority pollutants, for which criteria have been defined by EPA for environmental and human health effects, were examined. The pesticides included in the priority pollutants were not analyzed since these are not reasonably expected in retort leachate. Data on trace organics in retort leachate are listed in Section 5.5.

These organics analyses have been examined for indications of possible human and environmental health hazard. There is little, if any, toxicological information on many of the compounds identified in the GC/MS organics analysis. However, an evaluation can be made based on hazard information for similar compounds or for classes of compounds (see Section 5.5).

Among the priority pollutants determined, the major concerns would be for acenaphthene, pyrene, and benzene. Of these only benzene has been observed in retort leachate, the others were observed in retort water during production. Although acenaphthene is a rodent carcinogen, the level identified is well below the water quality criteria. The levels of benzene and pyrene both exceed the water quality criteria. However, these criteria are for lifetime exposure in drinking water and consumption of aquatic organisms and thus do not directly relate to the circumstances of Tract C-a and retort abandonment.

In conclusion, within the limits of the available information, there does not appear to be any organic compounds present at levels sufficient to individually produce significant toxic effects.



It should be noted that this conclusion is based on sampling leachate directly from the retort. As is discussed later, modeling of leachate impacts on the upper aquifer has indicated that concentrations at the tract boundary (approximately one mile from the MIS retorts) will be about one-tenth that at the retorts. This, with the proposed recirculation/leaching program, will further minimize the environmental risk of retort abandonment.

The use of upper aquifer water is very limited. Should upper aquifer water feed springs east of Tract C-a, some diluted components of leachate may occur in water used for irrigation in the Yellow Creek drainage or in water consumed by livestock which are present in the area for part of the year. The model analysis and examination of water quality criteria indicate that such impacts are not expected to be significant.

The monitoring program and associated data evaluation and response activities are based on criteria to protect these downstream uses (irrigation and livestock watering). The nearest potential surface releases are from springs located east of Tract C-a. The monitoring and modeling activities are designed to avoid exceeding defined water quality criteria at the tract boundary.

5.2 Support Information/Rationale for Monitoring Design

5.2.1 General Strategy

The retort abandonment program has been designed to mitigate the potential impacts on the quality of water in the upper aquifer. The general criterion for evaluating the success of this program is the avoidance of impacts on potential irrigation and livestock watering uses at the tract boundary, approximately one mile from Retort 1.

A mathematical model has been formulated to assist the evaluation of impacts on the upper aquifer (Law Engineering, 1981). Model projections

indicate that for a given concentration, Co, at the retort the expected concentration at the tract boundary is approximately 0.1 Co. Data collected during the abandonment program will be used to seek a validation of the model and better definition of model parameters.

During the initial abandonment phase (including recirculation/leaching) when water levels in the upper aquifer are above the water levels in Retort One, water flow will be toward the void spaces in the upper part of the retort. Thus water quality effects within the upper aquifer by either diffusion or mass transport will be negligible. Monitoring during this phase of abandonment should focus on water level measurements with relatively less frequent monitoring of water quality.

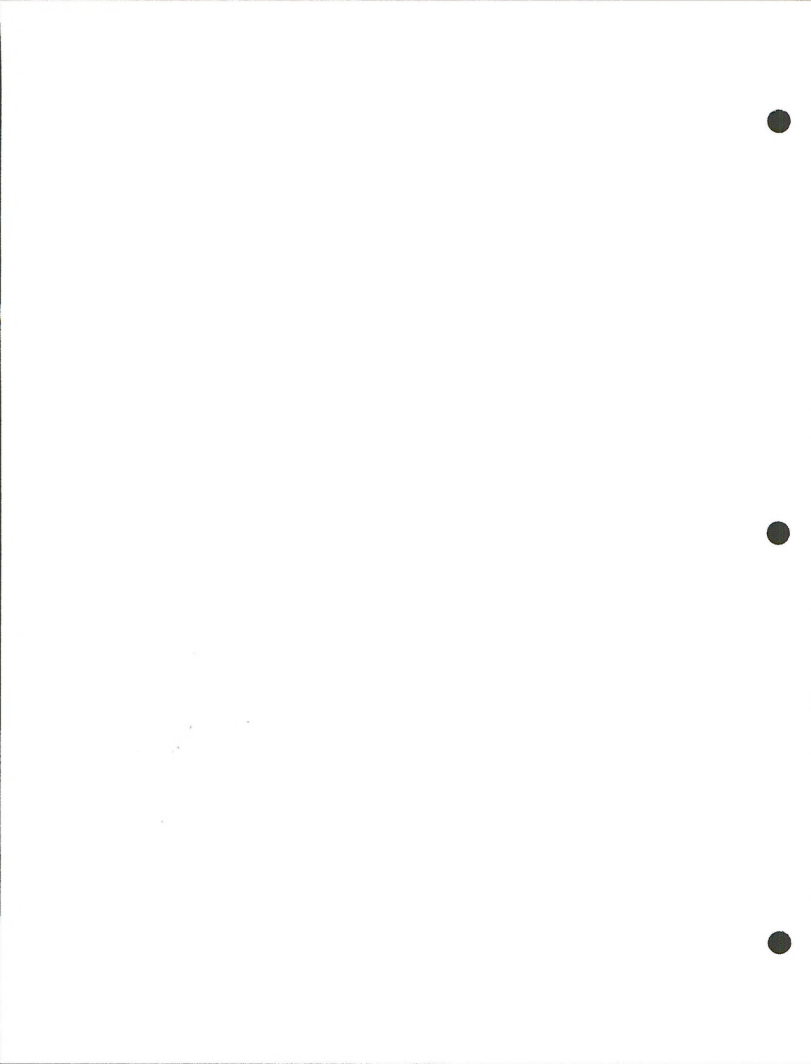
After the retort within the aquifer zone has been flooded, water quality monitoring will increase in frequency as the possibility of detecting leachate migration is increased. Monitoring prior to complete filling of the aquifer will also provide an opportunity to optimize field sampling and analysis operations.

After an upper aquifer gradient away from the retort is reestablished, the emphasis of the program should be on near-field water quality analysis with diminished frequency of water level measurement.

5.2.2 Monitoring Locations

Because measurable effects are only expected close to Retort One, sampling locations should be located as near as possible to the retort. To the extent possible, these locations should be located along the expected near-field (close to retort) flow lines (fractures). Given these requirements, the following are candidate sites for monitoring the effects of flooding:

- o GS-D1U and D3U (located upgradient (under normal gradient conditions) from Retorts Zero and One)



o GS-MDP2CU and GS-D5U located downgradient from the retorts.

The dewatering wells between GS-D1U and GS-D5U were located to take advantage of the major fractures during initial dewatering operations. These fractures may be expected to be major flow paths following re-flooding of Retort 1.

Pumping for sampling is preferred because a larger element of the aquifer is sampled and questions of water changes within the well bore are eliminated. Pumping can be accomplished by setting pumps in each monitor well or by using pump-packer systems (such as being used on Tract C-b) installed for each sample-collection activity.

None of the above monitor wells are located adequately close to Retort 1 to measure the near term effects of retort backfilling and leaching. An array of four new monitor wells should be constructed immediately adjacent to and downgradient (generally east) from Retort 1. These wells will be sampled in the A- and B-grooves, the major water producing zones. Dual completions or pump-packer systems will be employed. The sampling at two levels will allow better monitoring of the initial retort filling period and any concentration or density effects for leachate production.

In addition to the new monitor well array, a monitor well will be completed, if feasible, in Retort 1. This will provide data on the initial leaching process and early interpretations of potential impacts and monitoring needs. This retort-monitor well, if feasible, should also be constructed so as to allow sampling at multiple depths within the retort.

5.2.3 Constituents for Monitoring

Several criteria were used to select constituents for monitoring:

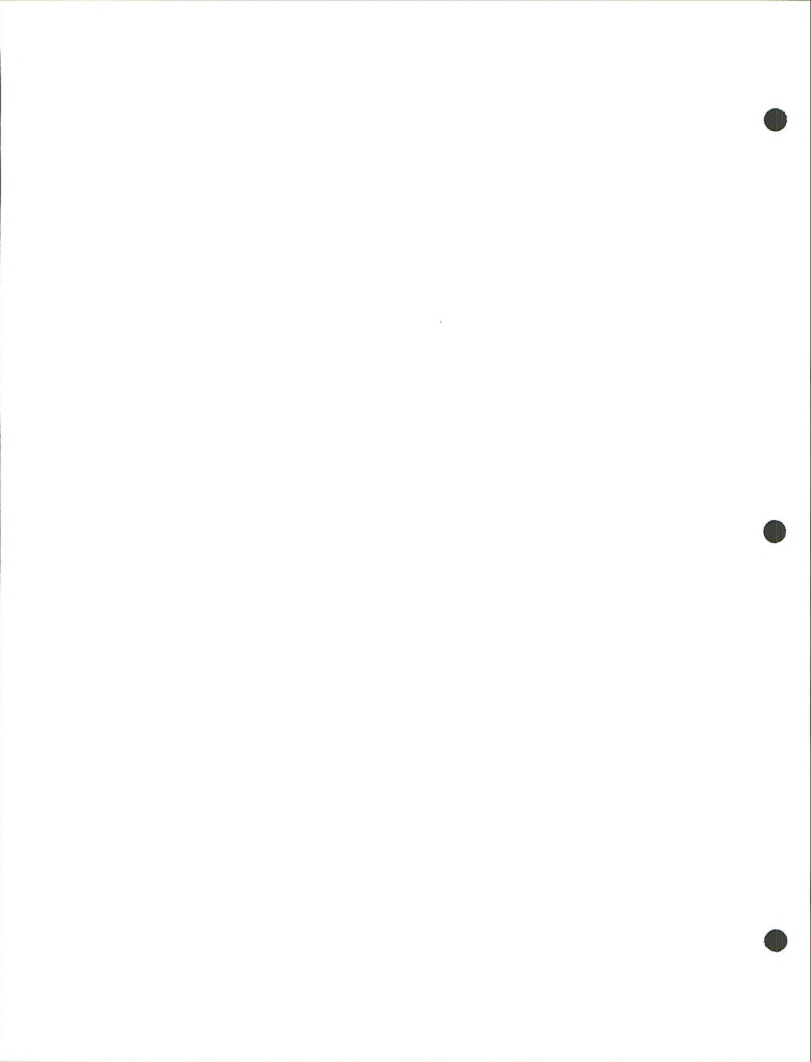


- o Utility as an indicator or tracer of leachate movement in the aquifer.
- o Potential toxicity or other environmental effects.
- o Utility for quality control purposes (e.g., ion balance calculations).
- o Efficiently (time and cost) of analysis.

The water quality constituents monitored by RBOSC were selected after an analysis of potential leaching of MIS retort wastes (RBOSC Environmental Monitoring Scope of Work, December 1980). By comparing potential leachate quality with ambient water quality, a basic set of constituents (BWQ) was designated which includes major inorganic ions, dissolved organic carbon (DOC) and selected trace constituents. Much of this evaluation was substantiated by examination of site-specific data from Retort 1 as shown in Table 5. Other trace constituents (TWQ) are monitored on a less frequent basis because of their diminished utility for impact analysis.

From the analyses summarized in Table 5, the following modifications were made in the 1980-defined basic water quality (BWQ) set of constituents:

- nitrate ($\text{NO}_3\text{-N}$) - deleted due to low concentrations in retort water relative to both upper aquifer and Yellow Creek waters; not useful as an indicator of neither impact nor change in water quality
- phosphate (PO_4) - deleted for same reasons as nitrate
- silica (SiO_2) - deleted for same reasons as nitrate
- arsenic (As), selenium (Se), mercury (Hg), vanadium (V) - deleted because observations for retort water (as for



natural water sources) are at or near level of analytical detection. Although identified as potentially mobile after MIS retorting by Peterson, et al (1982), these constituents do not appear useful indicators of impact or change from Tract C-a retort leachate

- lithium (Li) - added because of increased concentrations in retort water relative to natural waters; may be useful indicator
- lead (Pb) and nickel (Ni) - considered for inclusion because of potential importance (mobility and environmental sensitivity) noted by Peterson et al (1982); however were not included because were below detection levels in Tract C-a retort leachate (Table 5)

From these evaluations, the BWQ constituents listed in Table 6 will be used as the primary basis for monitoring of retort abandonment. Additional trace elements will be sampled only selectively in response to on-site and BWQ monitoring results.

Although data to date indicate a low level of environmental risk from trace organics in retort leachate (see Section 5.5), selected analyses are included in the proposed monitoring program. GC/MS analysis produces a great deal of data for which interpretative data do not exist. Criteria for the priority pollutants provide some measure of potential impacts, even though the exposure routes and duration (e.g. lifetime drinking water use) do not match the circumstances of the upper aquifer near Tract C-a. However, since some evaluation data exist, the priority pollutants were selected for monitoring of trace organics. Pesticides included in the priority pollutants will not be included because their presence in the retort leachate is not anticipated.



Table 6

Constituents for Water Quality Monitoring

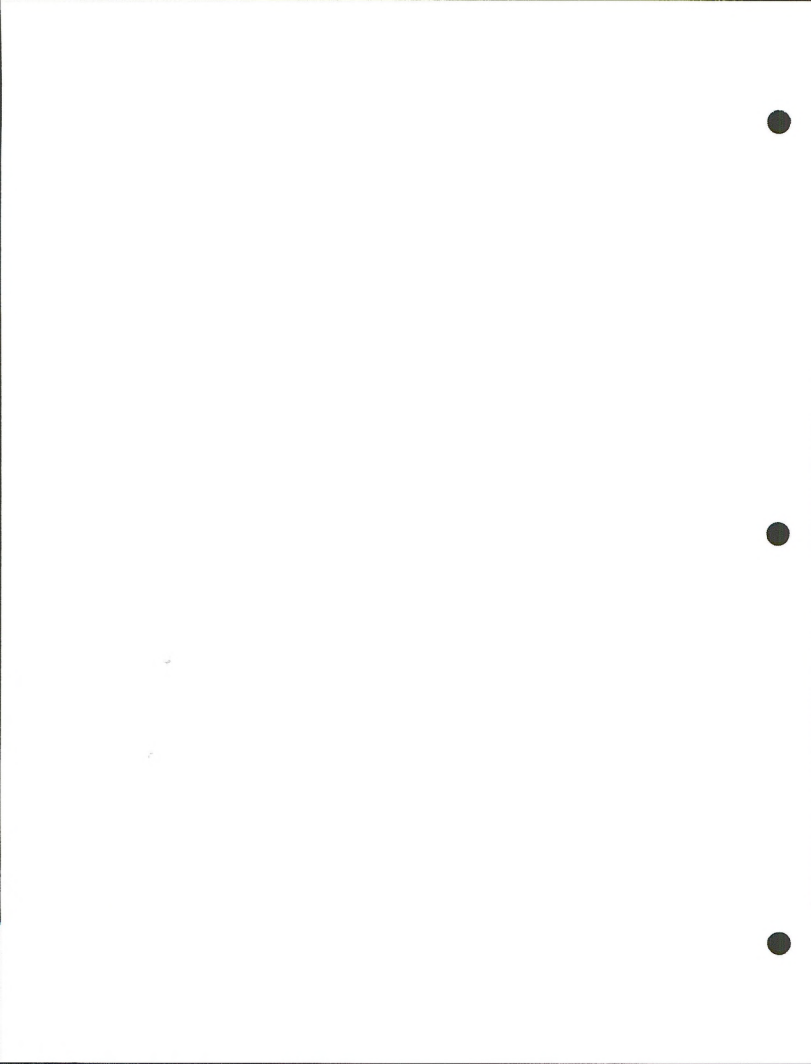
<u>Basic Water Quality (BWQ)</u>	<u>Trace Water Quality (TWQ)</u>
specific conductance	arsenic
TDS	aluminum
pH	beryllium
alkalinity	cadmium
calcium	chromium
magnesium	copper
potassium	iron
sodium	lead
chloride	manganese
bicarbonate	mercury
carbonate	nickel
sulfate	selenium
sulfide	strontium
fluoride	vanadium
ammonia	zinc
boron	
lithium	
molybdenum	
DOC	

In addition to laboratory analyses (e.g. BWQ), on-site monitoring of selected constituents will be utilized. Two criteria were used to select constituents for on-site monitoring

- o existing on-site capability or ability to implement easily on-site
- o utility of constituent as an indicator of impact or change

The following describes the utility of the constituents selected:

- o specific conductance, ammonia, fluoride -- instruments or chemical tests now in use on-site; levels in retort, leachate may initially be several times more than that of upper aquifer water (Table 5)
- o phenols, COD - COD currently analyzed on-site, phenol test kits (colorimetric or spectrophotometric methods) available. This would provide an on-site measure of organics in retort leachate. An extensive record of COD measurements in retort water and leachate has been developed. Phenols may be an important organic component.
- o pH - instruments in use on-site; some literature data indicate retort leachate may be more alkaline than upper aquifer water
- o sulfide, potassium - colorimetric or specific ion electrode methods available; both of these are expected in leachate concentrations several times that observed in natural waters. Thus they are likely good tracers for retort leachate although sulfide is more of a qualitative measure due to constituent instability.



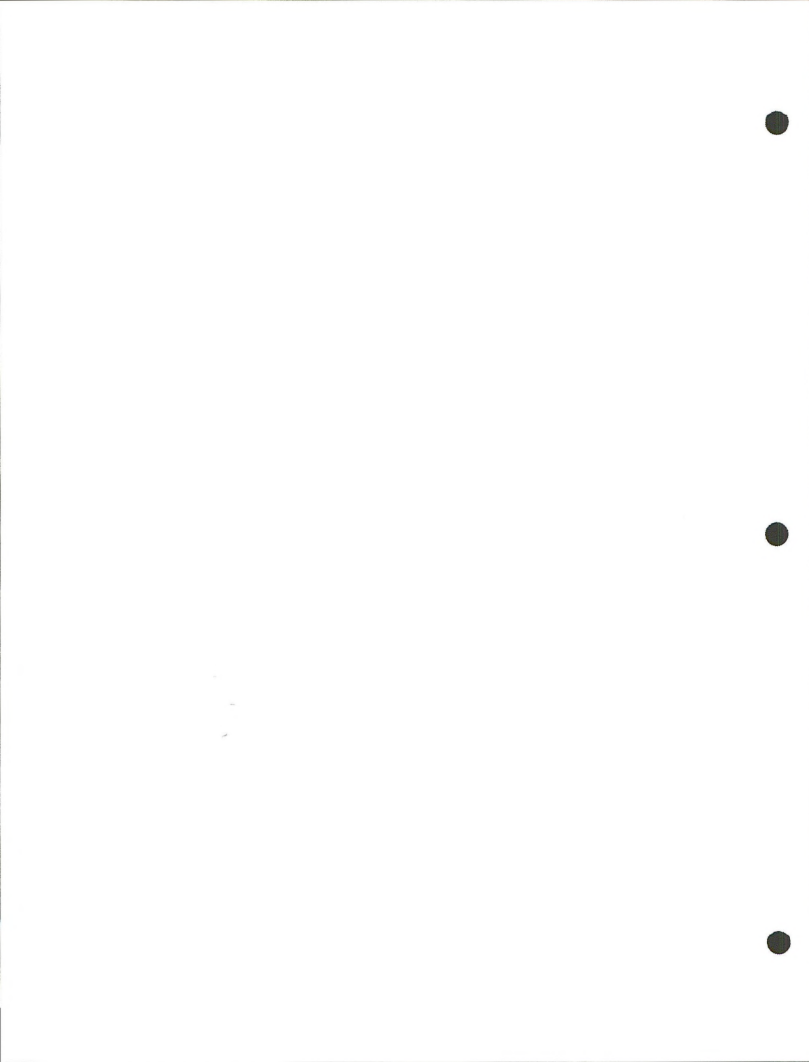
5.3 Monitoring Strategy

5.3.1 Monitor Well Locations

- o Upgradient from retorts: GS-D1U, GS-D3U
- o Retort well: within Retort 1 (if technically feasible)
- o Immediately downgradient (east) from Retort 1: four new monitor wells
- o Downgradient wells: GS-MDP2CU, GS-D5U

5.3.2 Well Completions

- o Upgradient and downgradient existing monitor wells will remain as presently completed
- o Retort well - separate completions in A-groove, B-groove and lower portion of the retort or have other capability to separate several levels within the retort. This well will provide data on leachate composition during initial flooding/leaching to allow analysis of the effectiveness of the pre-leaching and proposed monitoring program.
- o Immediately - downgradient (new) wells - separate completions in A-groove and B-groove or have other capability to separately sample A- and B-grooves



5.3.3 Monitoring Parameters

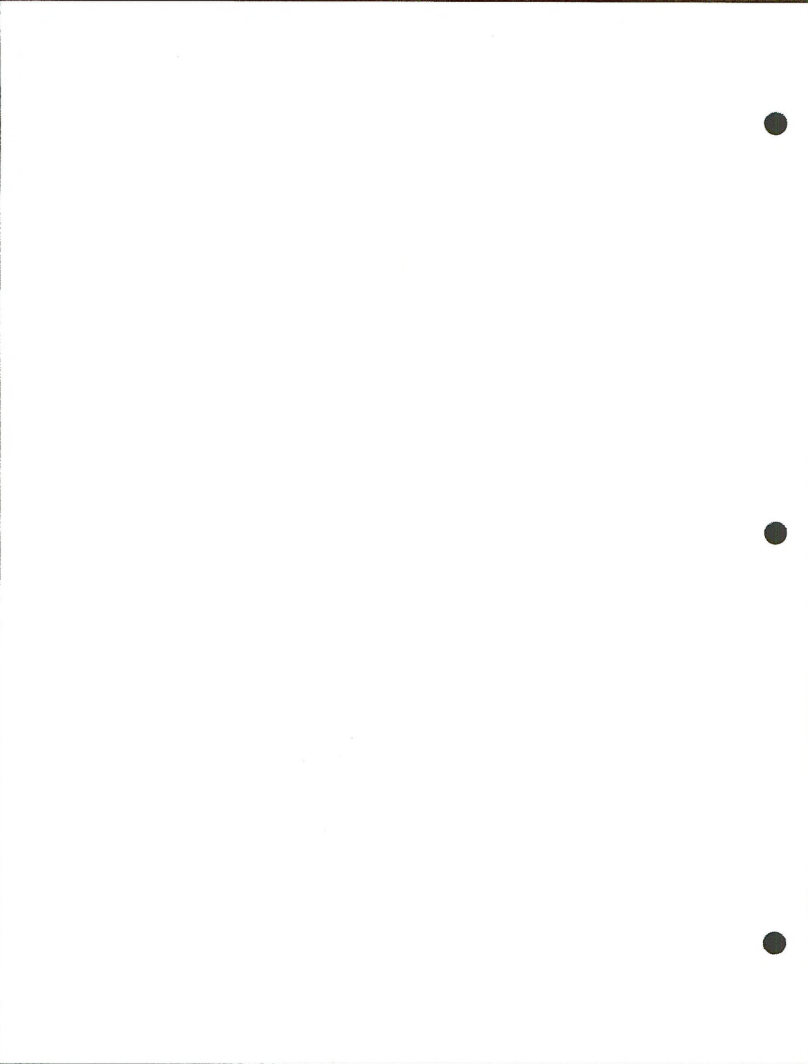
- o Water levels - electric sounder or related method
- o On-site analysis - specific conductance, ammonia, fluoride, pH, phenols, potassium, sulfide and COD
- o Contract laboratories
 - Basic water quality (BWQ) - see Table 6
 - Trace water quality (TWQ) - see Table 6
 - Trace organics - priority pollutants (non-pesticides)

5.3.4 Monitoring Schedule

- o Continue selected elements of current hydrology monitoring scope of work
 - semi-annual cone-of-depression mapping
 - quarterly springs and seeps monitoring (after Phase I (see following discussion), this will be increased to monthly sampling [to the extent the sites are accessible] for on-site analysis)
 - surface flume monitoring
 - semi-annual BWQ (see Table 6) for upper aquifer wells
- o PHASE I - initial period of flooding and circulation of water to cool and leach the retort; includes complete pump-down of retort following recirculation.

- daily measurement of water levels in mine and retort
- daily measurement of mine water and retort water pump flows (the latter measurement includes pumpage from retort, recycled to retort and discharge to ponds)
- daily on-site measurement of quality of mine water and pumpage from retort:
 - specific conductance
 - pH
 - ammonia.
 - fluoride
- weekly on-site measurement of quality of mine water and pumpage from retort:
 - sulfide
 - phenols
 - COD
 - potassium

Phase I will continue until the observed concentrations reach a steady state and then begin to fall or until a predetermined volume of water has been circulated through the retort. At this point the recirculation water will have become saturated and will be diluted by the continuing inflow of less saline ground water. During retort pump down, water level data for retort, mine and adjacent wells will be examined in an effort to evaluate near-field transmissivity of upper aquifer. This analysis will be used to rerun the Law Engineering model to further evaluate leachate impact potential.



- o PHASE II - initial retort filling phase; water levels in Retort 1 lower than water level in GS-D1U, D3U, MDP2CU
 - daily measurement of water levels in mine and retort (new retort well, if constructed)
 - weekly measurement of water levels in 4 new monitor wells, GS-D1U, D3U, MDP2CU, D5U
 - weekly on-site measurement of quality of mine water, retort well, 4 new monitor wells
 - specific conductance
 - pH
 - ammonia
 - fluoride
 - sulfide
 - phenols
 - COD
 - potassium
 - monthly BWQ sample collected from mine, retort well, 4 new monitor wells, GS-D1U, D3U, MDP2CU, D5U

Phase II will end and Phase III will be initiated when the following are observed in any of the 4 new monitor wells in four consecutive weekly samples:

- potassium greater than 10 mg/l
- fluoride greater than 6 mg/l
- specific conductance greater than 5000 micromhos
- sulfide greater than 20 mg/l

These observations with additional confirmatory data (see following discussion) would indicate that retort leachate constituents (see Table 1 data) have moved from the retort to the near-retort monitoring wells.

Ammonia and other constituents would also be expected to increase.

Rationale for Response to Shift from Phase II to Phase III: Recent observations of retort leachate have indicated several constituents which are natural "tracers". From Table 1, these include potassium, sulfide, ammonia which can be measured on-site. Leachate also exhibits elevated levels of specific conductance and fluoride which can also be measured on-site:

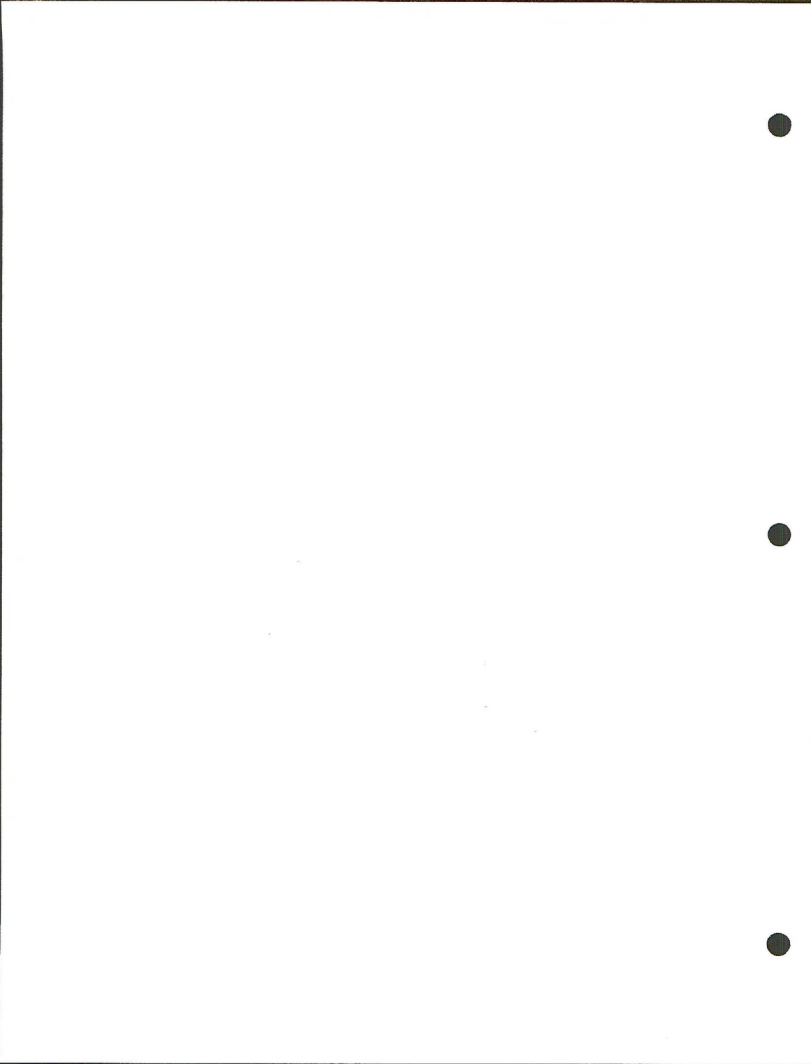
<u>Constituent</u>	<u>95 Percent Confidence Level, Upper Aquifer</u>	<u>Maximum Observed in Retort Water, 11/82-5/83</u>
potassium	4.5	1300
sulfide	11.7*	201
ammonia	1.8	52
sp. conductance	2524	7650
fluoride	3.6	10.1

* estimated from baseline data

Thus these constituents are good candidates for identifying flow of leachate components from the retort to monitor wells. Phase III will be initiated with the following observations in the four near-retort monitor wells:

- potassium greater than 10 mg/l
- sulfide greater than 20 mg/l
- specific conductance greater than 5000 micromhos per cm
- fluoride greater than 6 mg/l

These levels represent approximately twice the 95% confidence levels for the upper aquifer. Ammonia is also expected to be elevated in retort



leachate, however on-site measurements have been subject to some interferences. Thus ammonia will be used as an additional but more qualitative indicator of trends.

To avoid inappropriate response, confirmatory data will be collected as follows:

- o With the initial observation of one of the tracer constituents exceeding the response level, a duplicate sample will be collected as soon as possible for on-site analysis.
- o If the duplicate sample also exceed the response levels then sampling at the four near-retort monitoring wells will be increased from weekly to twice per week for on-site analysis and a BWQ sample will be collected from each of these four wells for confirmatory analysis.
- o If the biweekly samples continue to show the exceedence of response levels and the BWQ analysis confirms the presence of leachate (anticipated within 4 weeks of initial sampling), then Phase III monitoring will be initiated. (Note: Data on the initial concentrations in the retort and in the near-retort wells will be used to evaluate aquifer diffusivity. Additional analysis using Law Engineering model will be pursued at this point. A projection of the leachate movement into the aquifer and Phase III data will provide the basis for impact evaluation and determination of Phase III to Phase IV transition.)
- PHASE III - initiated in response to water quality changes in new monitor wells; retort leachate moving into the aquifer

- collect initial BWQ, TWQ and priority pollutant sample from mine, retort well (if constructed), 4 new monitor wells, GS-D1U, D3U, MDP2CU, D5U; repeat semi-annually for priority pollutants and trace constituents observed in measureable quantities
- twice per month BWQ from mine, retort well, 4 new monitor wells
- twice per week on-site measurement of quality (8 parameters) of mine water, retort well, 4 new monitor wells
- weekly water level measurement in mine, retort well, 4 new monitor wells, GS-D1U, D3U, MDP2CU, D5U
- PHASE IV - termination of monitoring of abandonment. Monitoring will be terminated when abandonment has been completed and bond release secured. Phase III monitoring data and projections using the Law Engineering model will be used to define the extent to expected impact. If an impact response (see following discussion) is not anticipated, then abandonment will be complete.

If Phase III monitoring after two years does not indicate a need for impact response (see following discussion), and the final six months of this monitoring does not show an increasing trend in BWQ constituents, then abandonment will be considered complete and monitoring terminated.

Should Phase III not be triggered (by detection of leachate constituents in near-retort monitor wells), Phase II monitoring will continue for two years. Should data from the retort and modeling indicate that no impact response (see



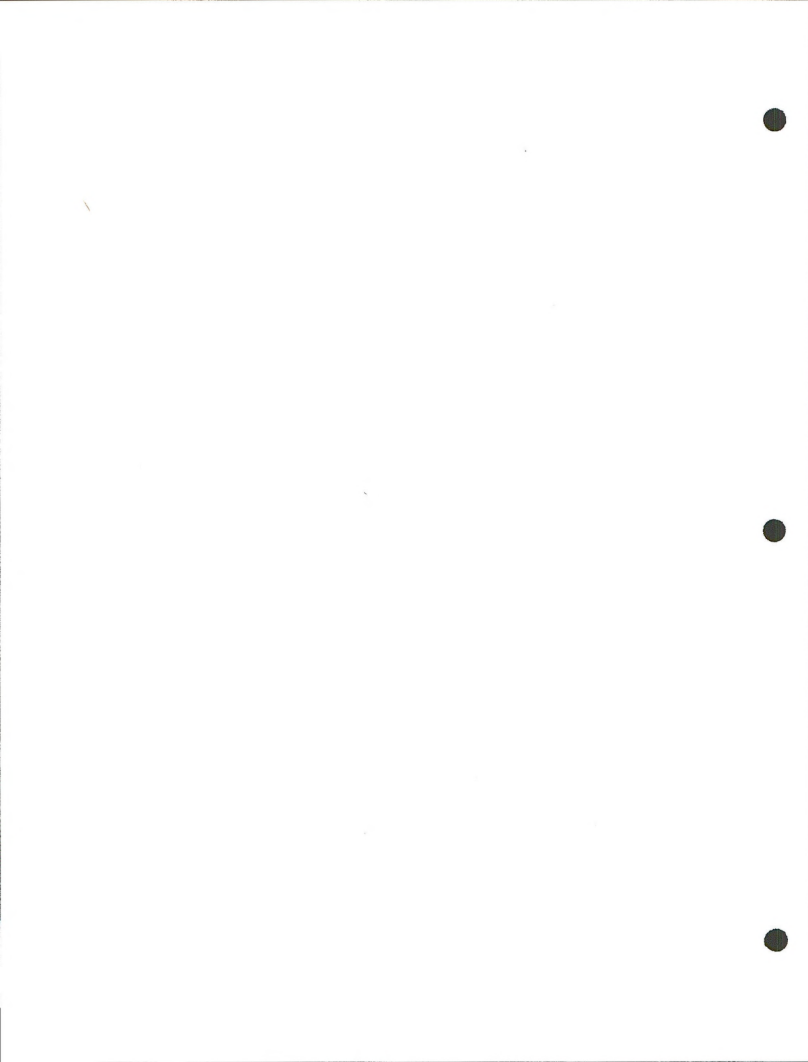
following discussion) is anticipated, and concentrations in the retort for the final six months of Phase II monitoring do not show an increasing trend in BWQ constituents, then abandonment will be considered complete and monitoring terminated.

- IMPACT RESPONSE - Action and related monitoring. Phase III observation in near-retort wells of potentially deleterious impacts to the upper aquifer will call for response by Rio Blanco. This response may include pumping of the retort directly to establish a small cone of depression with flow toward the retort. In this manner, contaminated water will be drawn back into the retort and discharged to evaporation ponds. Retort rubble grouting, placement of a grout curtain around the retort, or some yet to be developed procedure may be used to mitigate the impacts of retort leaching.

Model evaluations (Law Engineering, 1981) indicate that for a given concentration, C_0 , at the retort, the expected concentration at the tract boundary is approximately $0.1 C_0$. The following criteria have been selected to evaluate impacts:

- o boron - 5 mg/l - guideline for irrigation and toxicity to livestock
- o TDS - 5000 mg/l - guideline for livestock use
- o molybdenum - 0.5 mg/l - guideline for livestock effects
- o lithium - 2.5 mg/l - irrigation quality criterion

Using the 95 percent confidence level for concentrations of these constituents as a conservative indication of background water quality, allowable concentrations near the retort (those yielding tract boundary



concentrations less than the above criteria) are estimated as follows:

	Upper Aquifer 95% Confidence Level (a)	"Impact" Level (b)	Allowable Change at Tract Boundary b-a	Allowable Concentration at Retort 10(b-a)
TDS	2432	5000	2568	25,680
B	1.95	5	3.05	30.5
Mo	<.20	0.5	0.3	3.0
Li	.25	2.5	2.25	2205

Using a safety factor of two, the impact response of pumping of the retort will be triggered if concentrations in near-retort wells exceed the following concentrations:

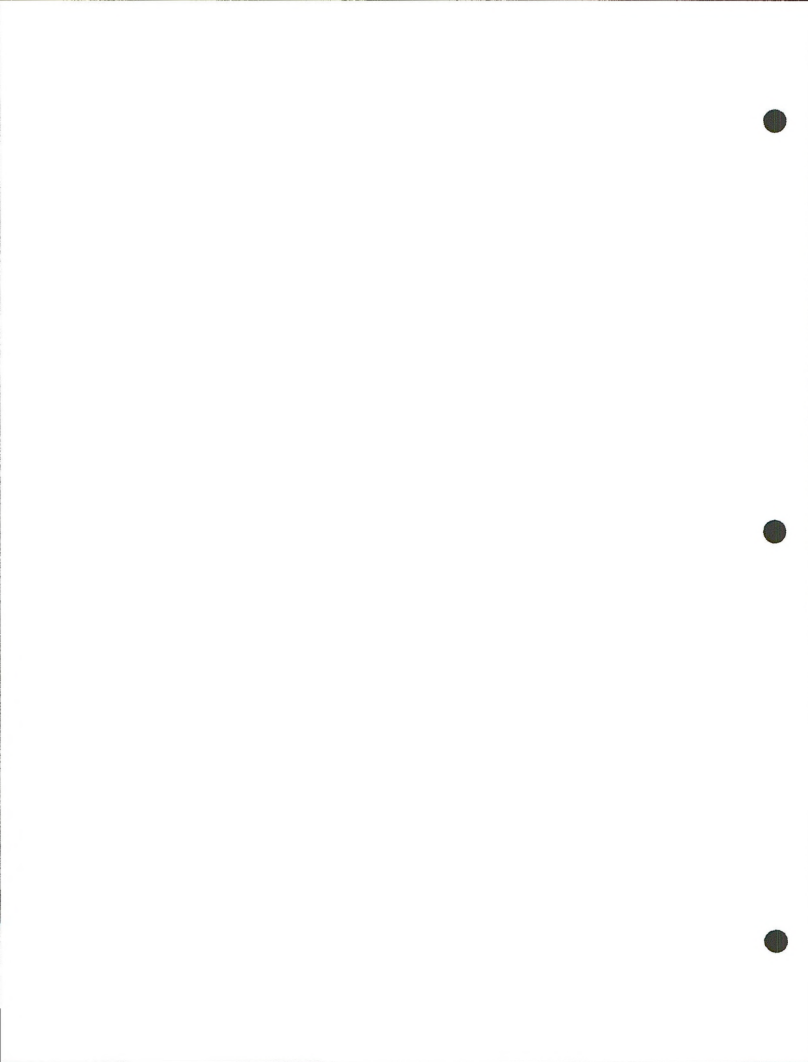
TDS	12840 mg/l
B	15.2 mg/l
Mo	1.5 mg/l
Li	11.2 mg/l

To avoid inappropriate response, confirmatory data will be collected as noted above for the Phase II to III transition. The initial response may be followed by additional mitigation measures.

5.4 Monitoring Data Evaluation

As data is collected or received from analytical laboratories, it is to be compared to defined evaluation criteria. Tables 7 and 8 show a comparison of upper aquifer water quality with Colorado standards for protection of aquatic biota, agriculture use and domestic supply. It is apparent from these data that upper aquifer water quality is already poor relative to these state standards. Thus these standards appear to be of only marginal significance for evaluation of water quality data.

Other guidelines for interpretation of water quality for agriculture



are as follows (University of California Cooperative Extension, 1973):

- o boron: alfalfa is boron tolerant up to about 5-6 mg/l; 5 mg/l is the guideline level for toxicity to livestock.
- o lithium: greater than 2.5 mg/l; recommended maximum concentration in irrigation water.



Table 7

Data Screens (Colorado Basic Standards Regulations)

Constituents	Standard (mg/l)			
	Aquatic Biota	Agriculture	Domestic Supply	Upper Aquifer P95(1)
pH	5-9	---	5-9	8.54(2)
NH ₃ -N	0.06 unionized	---	0.5	0.20(3)* (4)
F	---	---	2.4 (maximum)	3.61*
NO ₃ -N	---	---	10	1.33
B	---	.75	---	1.95*
Cl	---	---	250	40.46
SO ₄	---	---	250	846.4*

- (1) Upper aquifer data base 95% confidence limit
- (2) Field data
- (3) NH₃-N measurement - ionized + unionized = 1.79 mg/l, at pH = 8.5 and temperature of 20°C, 11% is unionized or 0.20 mg/l
- (4) * exceeds at least one criteria

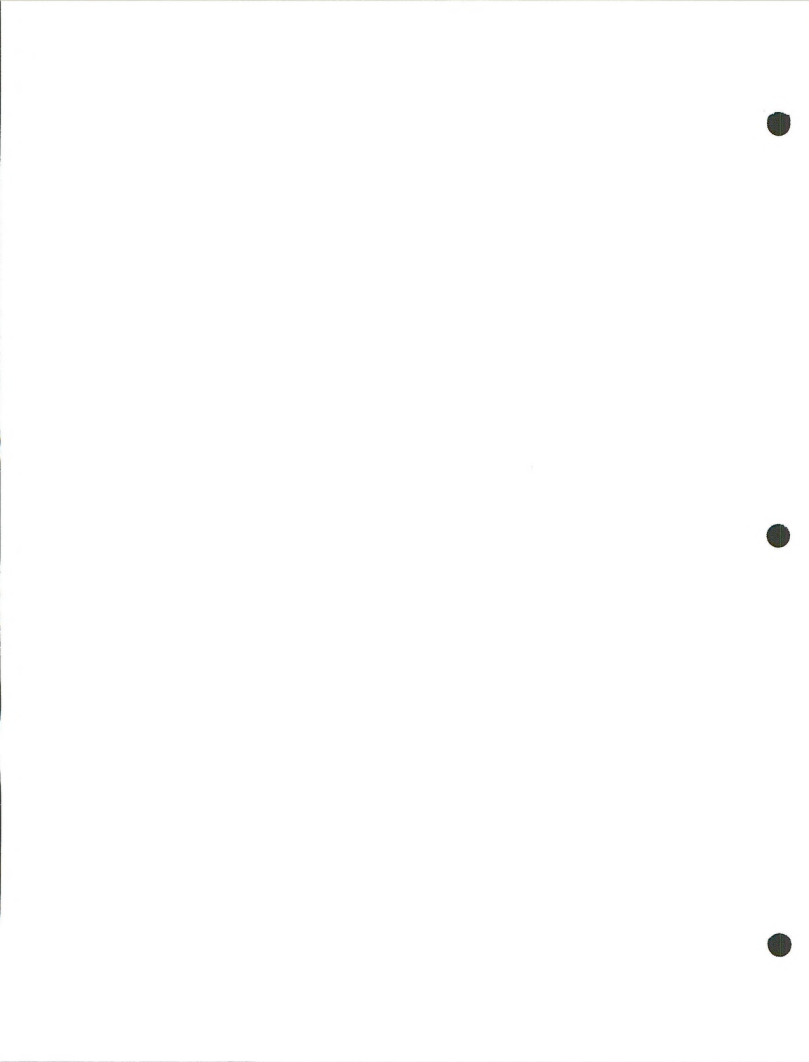


Table 8

Data Screens (Colorado Basic Standards Regulations)

Total Metals	Standard (mg/l)			
	Aquatic Biota(1)	Agriculture	Domestic Supply	Upper Aquifer p95(2)
Al (sol)	0.1	---	---	---
As	0.05	0.1	0.05	.02
Ba	---	---	1.0	1.00*(3)
Be	0.9	0.1	---	.01
Cd	0.01	0.01	0.01	.01*
Cr ⁺³	0.1	0.1	0.05	---
Cr ⁺⁶	0.025	0.1	0.05	.05 (total)*
Cu	0.02	0.2	1.0	.10*
Fe	1.0	---	0.3 (sol)	11.02*
Pb	0.1	0.1	0.05	1.00*
Mn	1.0	0.2	0.05 (sol)	.40*
Hg	0.00005	---	0.002	.0003*
Ni	0.3	0.2	---	.05
Se	0.05	0.02	0.01	.01*
Zn	0.30	2.0	5.0	1.33*

(1) Hardness = 3-400

(2) Upper aquifer 95% confidence level

(3) Exceeds at least one criteria listed



- o molybdenum: greater than 0.5 mg/l; estimated toxic level for livestock.
- o total dissolved solids criteria for livestock:
 - less than 1,000 mg/l - excellent
 - 1,000 - 2,999 mg/l - very satisfactory
 - 3,000 - 4,999 mg/l - satisfactory
 - 10,000 mg/l - toxic

The 95 percent confidence level for the upper aquifer for these constituents is boron, 1.95 mg/l; lithium, 0.25 mg/l; molybdenum, <.20 mg/l, and TDS, 2432 mg/l. These criteria seem more appropriate than state standards to evaluate abandonment monitoring data and have been used to define response levels as noted in the monitoring strategy.

The evaluation of organics data is complex because standards typically do not exist. Dissolved organic carbon measurements will be evaluated using historical observations as outlined above. Criteria have been defined by EPA for selected trace organics (Table 9). Most of the levels listed in this table are far greater than concentrations observed in retort water samples (see Section 5.5). These criteria and previous observations will be used to evaluate abandonment monitoring data.

5.5 Leachate Water Quality Data

Table 10 lists retort leachate quality data for proposed BWQ monitoring constituents for the period 11 November 1982 through 01 August 1983. Other chemistry data collected during this period are listed in Table 11.

Trace organics data from analyses of retort leachate are listed in Tables 12 and 13. As shown in these tables, a large number of trace

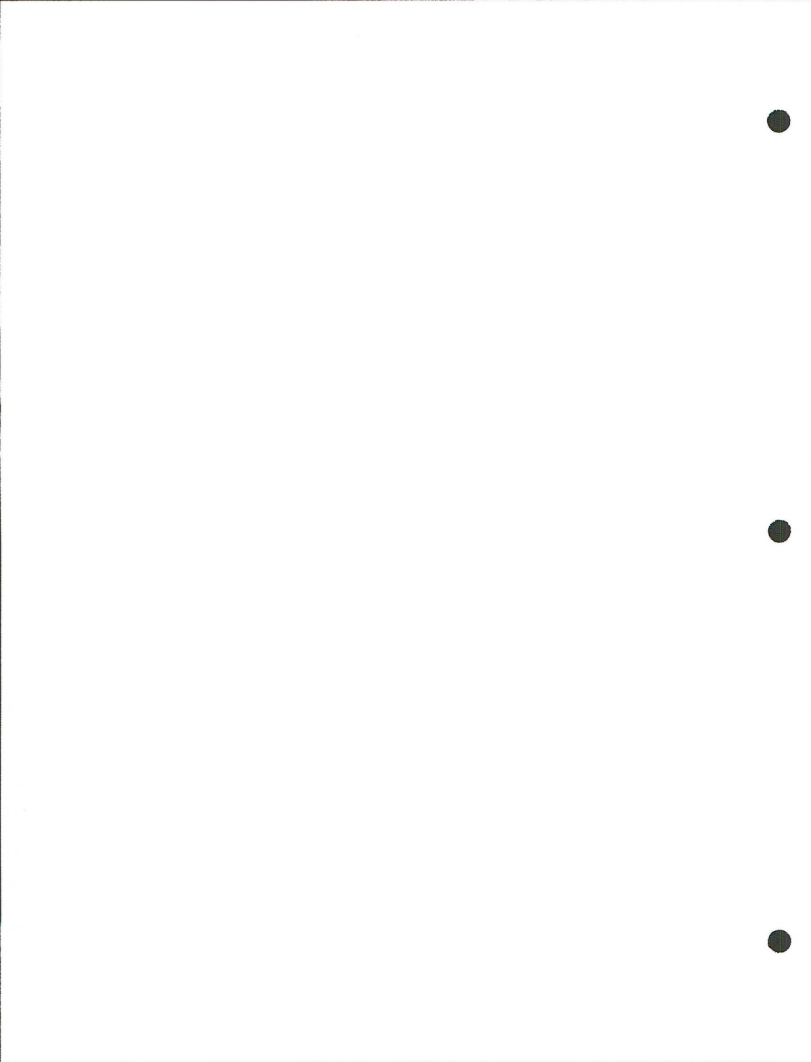


Table 9

Evaluation Criteria for Trace Organics:
(from FR 45-231, 11/28/80 - WQ criteria documents)

	<u>Aquatic Life, ppb</u> (1)	<u>Human Health, ppb</u>
Benzene	5,300	6.6 (2)
Ethylbenzene	32,000	1400
Toluene	17,500	14,300
2-4 Dimethylphenol	2,120	400 (3)
Phenol	10,200 2,560	3,500 300 (3)
Isophorone	117,000	5,200
Acenaphthene	1,700	20 (3)
Naphthalene	2,300 620 (4)	---

(1) acute toxicity

(2) potential carcinogen, one additional cancer per 10^5 people at this concentration

(3) taste and odor problems

(4) chronic toxicity

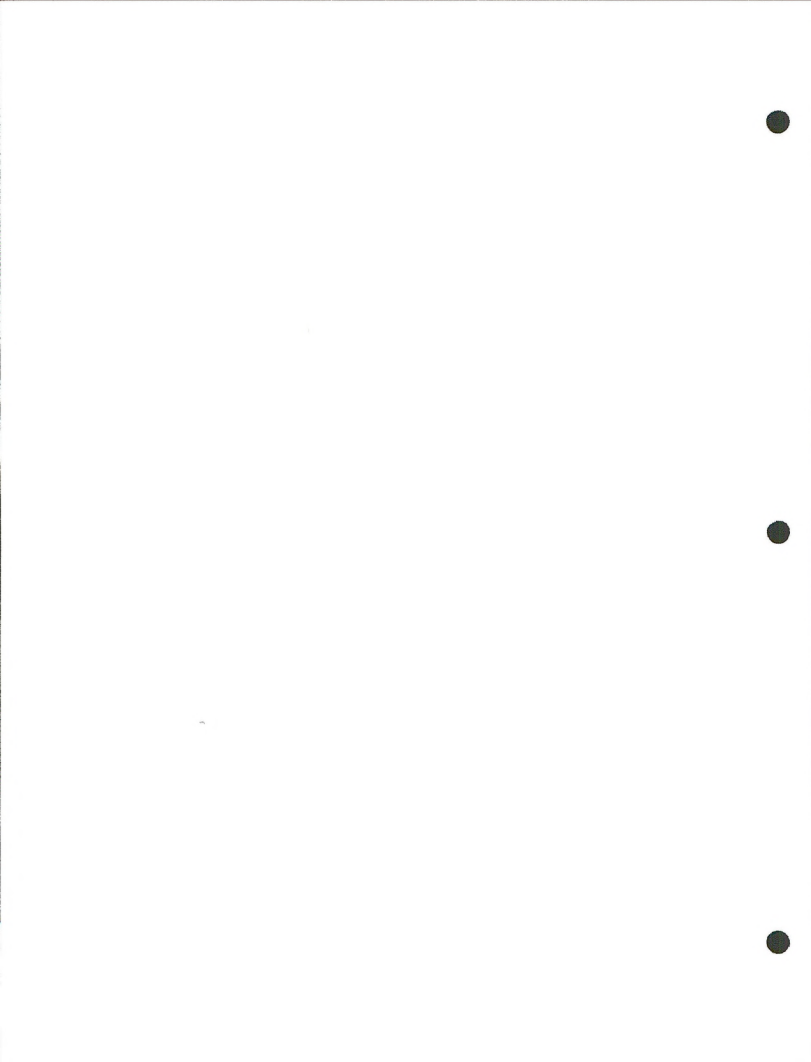


Table 10. Retort Leachate Water Quality Analysis - Proposed BWQ Constituents

Date:	11/09/82	11/22/82	12/20/82	12/29/82	01/12/83	01/31/83	02/16/83	03/02/83	03/17/83
<u>Constituents</u>									
ec	1530	3000	3700	3250	3950	5410	5150	5200	4900
TDS	1206	2572	3092	2328	3272	3988	3744	3710	3606
pH	8.0	8.3	8.5	8.2	8.0	8.3	8.4	8.3	8.2
alkalinity	490	366	513	607	503	595	590	647	630
calcium	67	160	116	84	91	100	88	85	82
magnesium	88	70	58	60	56	59	59	62	61
potassium	2.5	220	334	216	384	560	510	490	480
sodium	220	410	550	490	600	670	710	580	660
chloride	8.7	57.2	61.7	76.4	88	191.6	193.6	197.1	208.5
bicarbonate	580	419	544	715	584	637	676	761	721
carbonate	<1	<1	20	<1	<1	<1	8.2	<1	<1
sulfate	498	1459	1590	1080	1719	2073	1975	1850	1890
sulfide	---	---	25.8	62	<.02	49.8	50.5	80.8	135
fluoride	1.9	4.8	7.5	8.2	7.9	6.4	8.4	7.4	4.5
ammonia	2.86	12.0	21.6	17.2	18.5	33.9	32.3	33.5	19.8
boron	0.17	1.42	2.25	1.50	2.16	2.72	2.03	2.06	2.14
lithium	---	2.02	2.60	1.71	2.64	3.40	3.16	2.80	2.60
molybdenum	<0.1	1.1	<0.1	0.2	0.5	0.7	0.8	0.6	0.7
DOC	7	33	36	23	50	43	39	38	34



Table 10. Retort Leachate Water Quality Analysis - Proposed BWQ Constituents
(continued)

Date:	03/31/83	04/21/83	05/04/83	05/18/83	06/06/83	06/17/83	07/07/83	07/18/83	08/01/83
<u>Constituents</u>									
ec	4900	3870	4390	4500	5900	5950	6120	6950	7650
TDS	3528	3414	3610	3418	4070	1676	5088	5480	5856
pH	8.3	8.8	8.7	8.7	8.4	8.5	8.8	8.7	8.6
alkalinity	666	746	765	716	725	784	834	804	743
calcium	74	65	63	60	58	56	57	57	51
magnesium	61	59	57	56	56	52	56	53	48
potassium	480	440	490	450	740	720	850	980	1300
sodium	640	640	660	620	600	840	890	960	940
chloride	206	225	161.3	197.2	224	362	365	472	70.7
bicarbonate	776	755	776	735	802	829	807	797	757
carbonate	<1	60.9	60.9	49.3	21.1	39.9	81	68.1	46
sulfate	1782	1664	2007	1644	2119	2090	2710	2971	3243
sulfide	139	124.3	114	107	128	117.2	149.1	81.4	201
fluoride	7.1	8.9	9.2	9.6	7.9	9.2	9.5	9.4	10.1
ammonia	17.9	24.8	27.3	22.3	17.0	20.04	54	52	40.6
boron	1.09	1.77	2.02	2.05	2.54	2.60	2.67	3.63	3.75
lithium	2.73	2.32	---	2.08	---	2.60	---	2.40	---
molybdenum	0.1	<0.1	0.2	<0.1	0.4	0.4	0.5	0.6	0.8
DOC	43	33	47	42	56	58	77	64	78

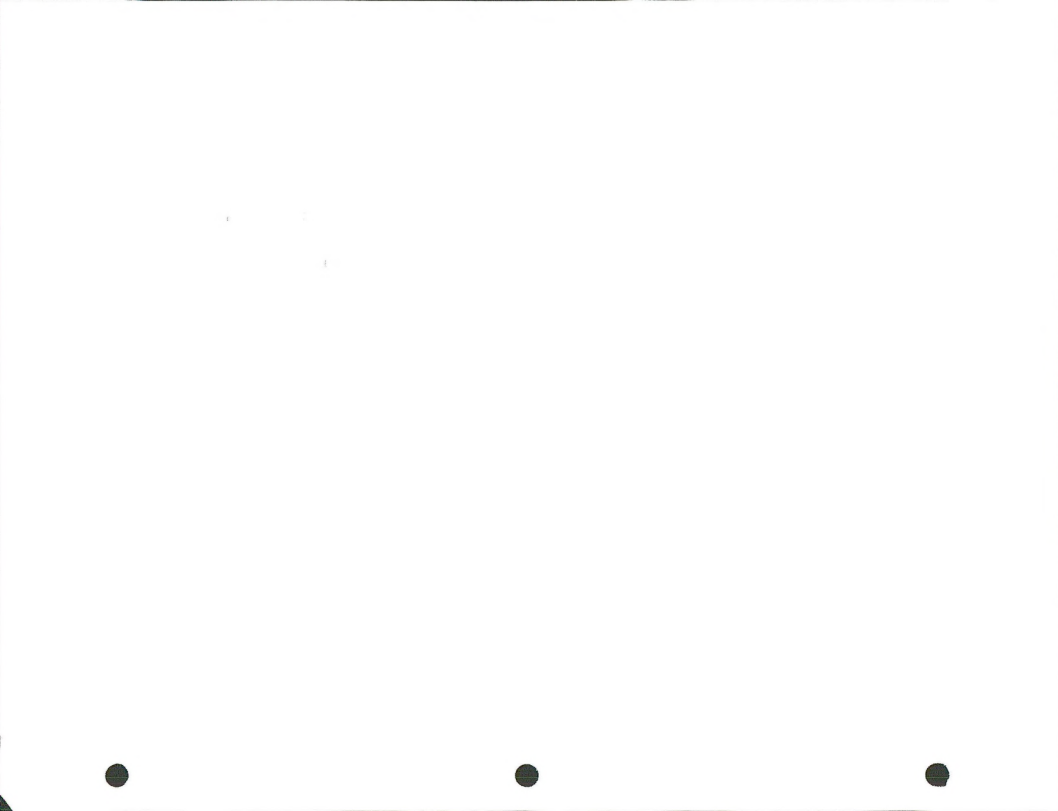


Table 11. Additional Analyses of Retort Water Leachate

Date:	11/09/82	11/22/82	12/20/82	12/29/82	01/12/83	01/31/83	02/16/83	03/02/83	03/17/83
Constituents									
nitrate	<0.1	<0.1	<0.1	<0.1	0.52	<0.1	<0.1	<0.1	<0.1
phosphate	0.02	0.02	0.31	<0.01	0.01	0.04	<0.01	0.02	0.04
silica	25	28	26	23	24	22	23	25	23
aluminum	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
arsenic	<0.01	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.01
barium	---	<0.1	<0.1	0.3	0.1	<0.1	0.2	0.1	<0.1
beryllium	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
bismuth	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
cadmium	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
chromium	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
copper	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
gallium	---	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
germanium	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
iron	0.24	0.82	<0.12	0.14	0.23	0.11	0.21	0.28	0.11
lead	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
manganese	---	0.04	0.03	0.02	0.03	<0.01	<0.01	<0.01	0.02
mercury	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	0.0004	<0.0003
nickel	---	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
selenium	<0.01	0.01	<0.02	0.02	<0.01	0.01	<0.01	<0.01	0.01
strontium	---	7.6	6.4	6.0	5.8	6.3	6.3	5.8	5.6
titanium	---	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
vanadium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
zinc	---	0.14	0.01	0.05	0.02	0.08	0.06	0.07	<0.01
zirconium	---	<10	<10	<10	<10	<10	<10	<10	<10

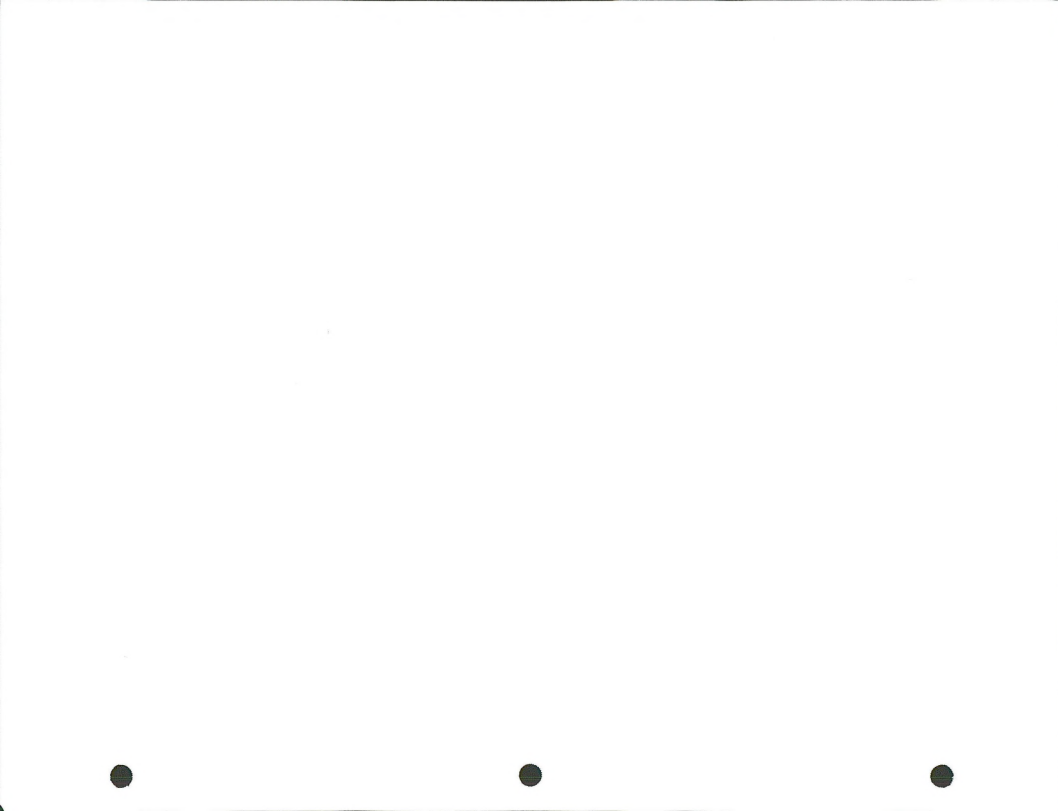


Table 11. Additional Analyses of Retort Water Leachate
(continued)

Date:	03/31/83	04/21/83	05/04/83	05/18/83	06/06/83	06/17/83	07/07/83	07/18/83	08/01/83
<u>Constituents</u>									
nitrate	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
phosphate	0.03	<0.01	0.01	<0.01	<0.01	0.03	0.03	0.06	0.04
silica	23	21	24	23	23	23	25	24	27
aluminum	<0.1	<0.1	---	<0.1	---	0.1	---	<0.1	---
arsenic	0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01
barium	<0.1	0.1	---	0.1	---	0.2	---	<0.1	---
beryllium	<0.01	<0.01	---	<0.01	---	<0.01	---	<0.01	---
bismuth	<0.01	<0.01	---	<0.01	---	<0.01	---	<0.01	---
cadmium	<0.01	<0.01	---	<0.01	---	<0.01	---	<0.01	---
chromium	<0.01	<0.01	---	<0.01	---	<0.01	---	<0.01	---
copper	<0.01	<0.01	---	<0.01	---	<0.01	---	<0.01	---
gallium	<0.5	<0.5	---	<0.5	---	<0.5	---	<0.5	---
germanium	<0.1	<0.1	---	<0.1	---	<0.1	---	<0.1	---
iron	0.14	0.12	0.07	0.18	0.14	0.15	0.12	0.08	0.08
lead	<0.01	<0.01	---	<0.01	---	0.01	---	<0.01	---
manganese	<0.01	0.01	---	0.01	---	<0.01	---	<0.01	---
mercury	0.0004	<0.0003	<0.0003	<0.0003	0.0004	<0.0003	<0.0003	<0.0003	<0.0003
nickel	<0.05	<0.05	---	<0.05	---	<0.05	---	<0.05	---
selenium	0.01	0.01	0.01	<0.01	0.01	0.01	<0.01	<0.01	<0.01
strontium	5.6	4.7	---	4.4	---	4.5	---	4.6	---
titanium	<0.5	<0.5	---	<0.5	---	<0.5	---	<0.5	---
vanadium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
zinc	0.01	<0.01	---	<0.01	---	<0.01	---	0.02	---
zirconium	<10	<10	---	<10	---	<10	---	<10	---



Table 12

GC/MS Organic Analyses of Waters Sampled from Backflooded
Rio Blanco Retort 1 (US Geological Survey, sampled
November 1982)

(ug/l, micrograms per liter; NA, not analyzed; ND, not detected)

Compound	Retort Leachate Water (ug/l)	Evaporation Pond Water (ug/l)
<u>Aliphatic monocarboxylic acids</u>		
Acetic acid ¹	680	250
Propanoic acid ¹	101	92
2-Methylpropanoic acid ¹	291	260
Butanoic acid ¹	497	254
2-Methylbutanoic acid ²	176	104
3-Methylbutanoic acid ²	232	120
Pentanoic acid ¹	438	344
C-6 acid isomers ²	573	198
Hexanoic acid ¹	520	330
C-7 acid isomers ²	271	101
Hepanoic acid ¹	612	262
C-8 acid isomers ²	150	73
Octanoic acid ¹	295	79
C-9 acid isomers ²	126	50
Nonanoic acid ¹	48	16
C-10 acid isomers ²	98	20
Decanoic acid ¹	29	8
C-11 acid isomers ²	38	15
Tridecanoic acid ²	ND	3



Table 12 (continued)

Compound	Retort Leachate Water (ug/l)	Evaporation Pond Water (ug/l)
Tetradecanoic acid ²	9	14
Pentadecanoic acid ²	ND	12
9-Hexadecenoic acid ²	8	19
Hexadecanoic acid ²	36	46
Hepatadecanoic acid ²	ND	4
9-Octadenoic acid ²	4	10
Octadecanoic acid ²	12	20
<u>Aliphatic dicarboxylic acids</u>		
Ethanedioic acid ²	681	185
Propanedioic acid ²	179	12
Pentanedioic acid ²	327	40
C-6 acid isomers ²	231	60
C-7 acid isomers ²	104	14
C-8 acid isomers ²	19	2
C-9 acid isomers ²	22	8
C-10 acid isomers ²	10	3
<u>Aromatic acids</u>		
Benzoic acid ²	123	40
2-Methylbenzoic acid ²	18	5
3-Methylbenzoic acid ²	40	14
4-Methylbenzoic acid ²	12	4
Dimethylbenzoic acid isomers ²	40	15
Trimethylbenzoic acid isomers ²	10	9

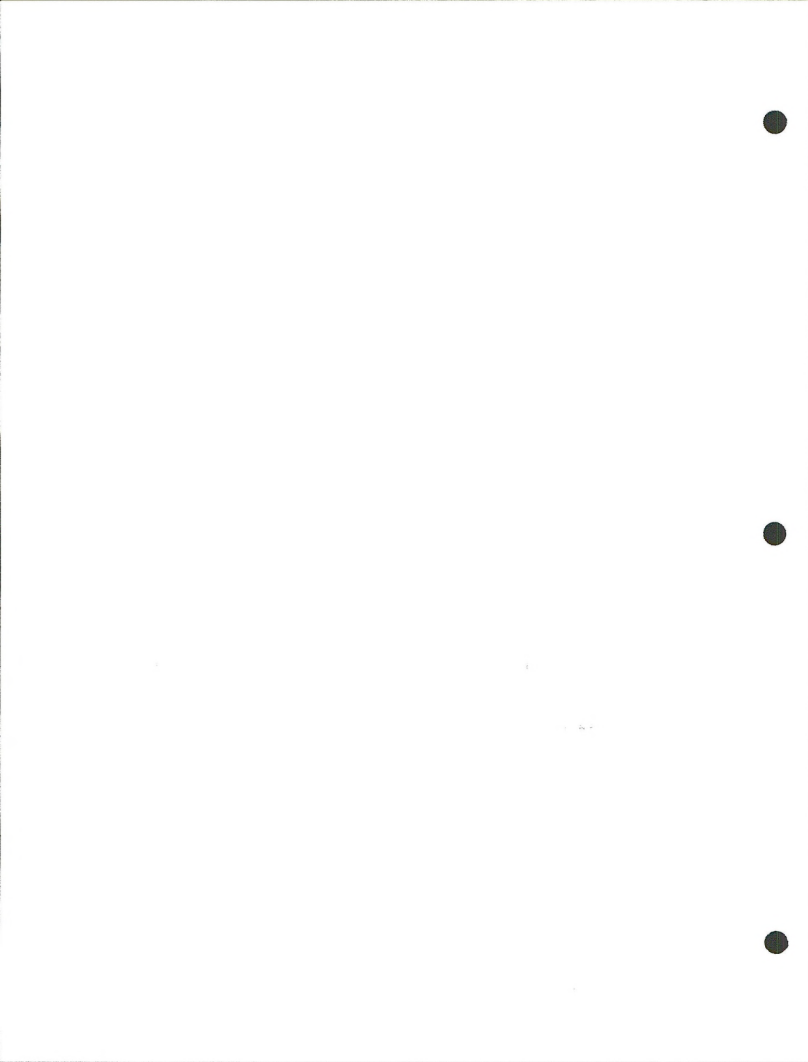


Table 12 (continued)

Compound	Retort Leachate Water (ug/l)	Evaporation Pond Water (ug/l)
<u>Phenols</u>		
Phenol ¹	196	ND
2-Hydroxytoluene ¹	92	10
3- and 4-Hydroxytoluene ¹	238	36
1,2-Dimethyl-4-Hydroxybenzene ¹	27	9
Dimethylhydroxybenzene isomers ²	236	167
<u>Aromatic amines</u>		
Aniline ²	83	268
Aminotoluene isomers ²	63	214
Pyridine ¹	68	241
2-Methylpyridine ¹	35	57
3- and 4-Methylpyridines ¹	36	96
2,6-Dimethylpyridine ¹	29	54
Dimethylpyridine isomers ²	56	122
C-3 alkylpyridine isomers ²	159	194
C-4 alkylpyridine isomers ²	151	178
C-5 alkylpyridine isomers ²	90	85
C-6 alkylpyridine isomers ²	38	53
C-7 alkylpyridine isomers ²	6	7
C-8 alkylpyridine isomers ²	4	3
Quinoline ¹	7	11
Isoquinoline ¹	4	4
Methylquinoline and methyl isoquinoline isomers ²	37	55

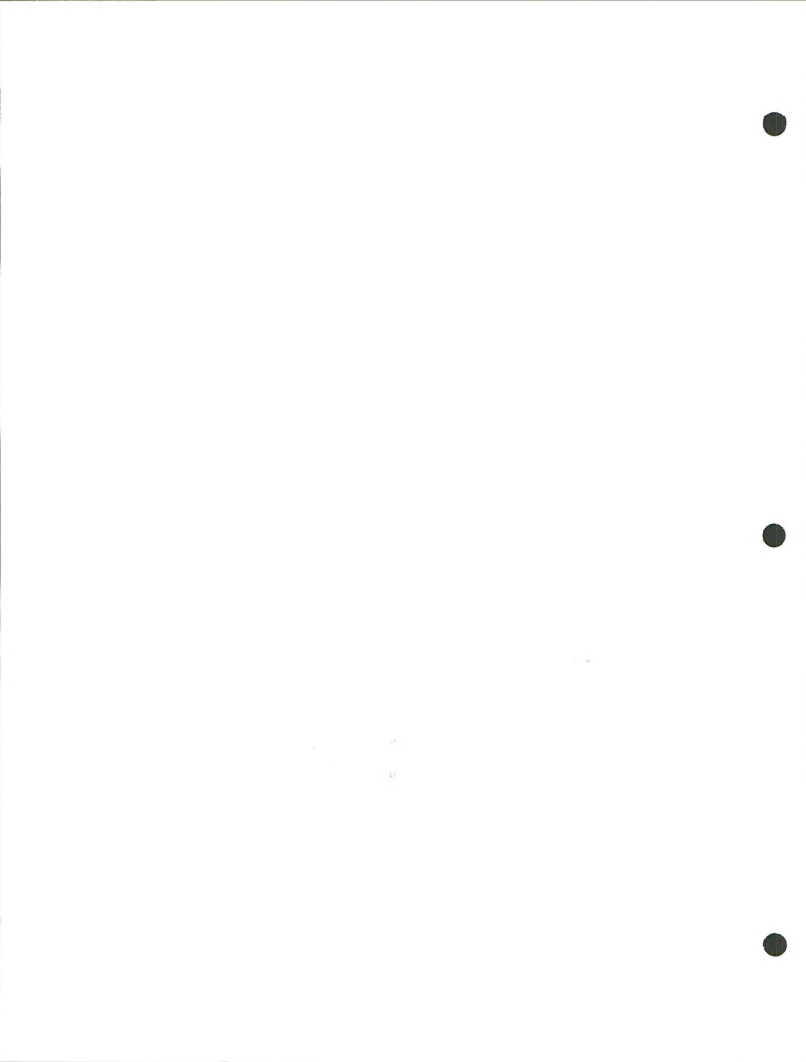


Table 12 (continued)

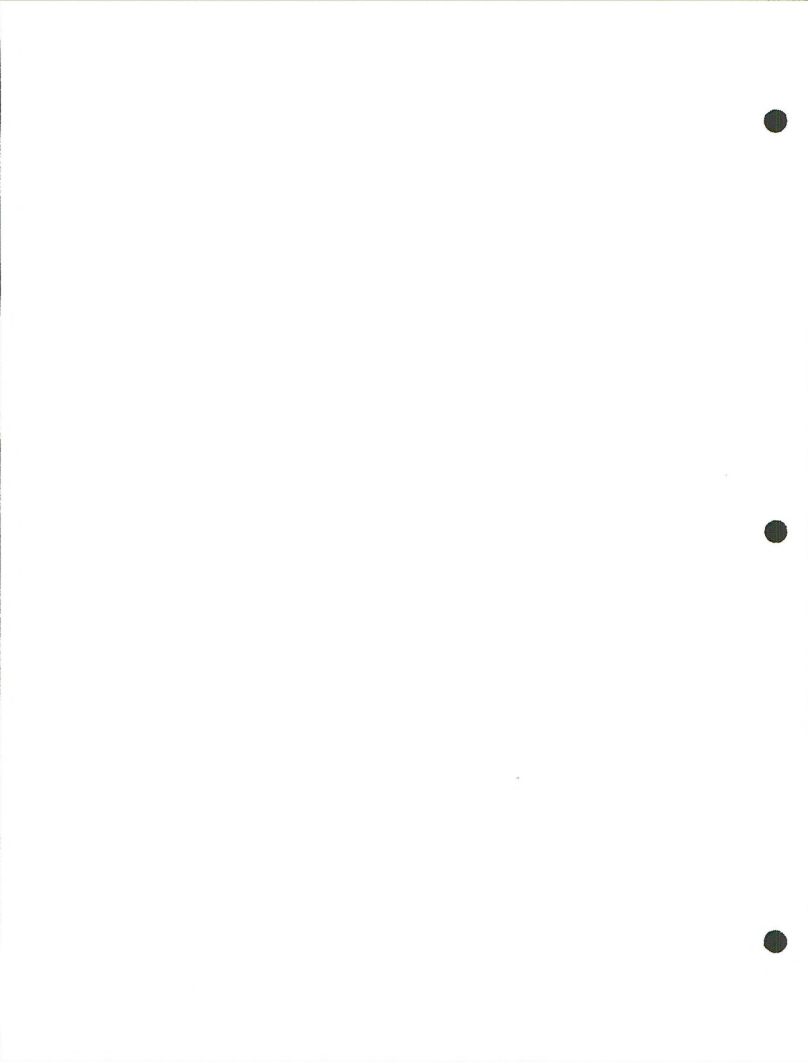
Compound	Retort Leachate Water (ug/l)	Evaporation Pond Water (ug/l)
C-2 alkylquinoline and C-2 alkylisoquinoline isomers ²	65	96
C-3 alkylquinoline and C-3 alkylisoquinoline isomers ²	20	29
N-phenylbenzeneamine ²	5	4
N-phenyltolueneamine isomers ²	15	20
Carbazole ²	1	ND
Acridine ²	.8	1.0
Benzo-f-quinoline ²	ND	1.0
Methylbenzo-f-quinoline isomer ²	.7	ND
<u>Hydroxypyridines</u>		
2-Hydroxypyridine ¹	57	NA
4-Hydroxypyridine ¹	3	NA
2-Hydroxy-6-methylpyridine ¹	94	NA

¹ Identifications confirmed and quantified with standards.

² Tentative identifications and quantification only by gas chromatography-mass spectrometry.

Table 13
Priority Pollutant Analysis

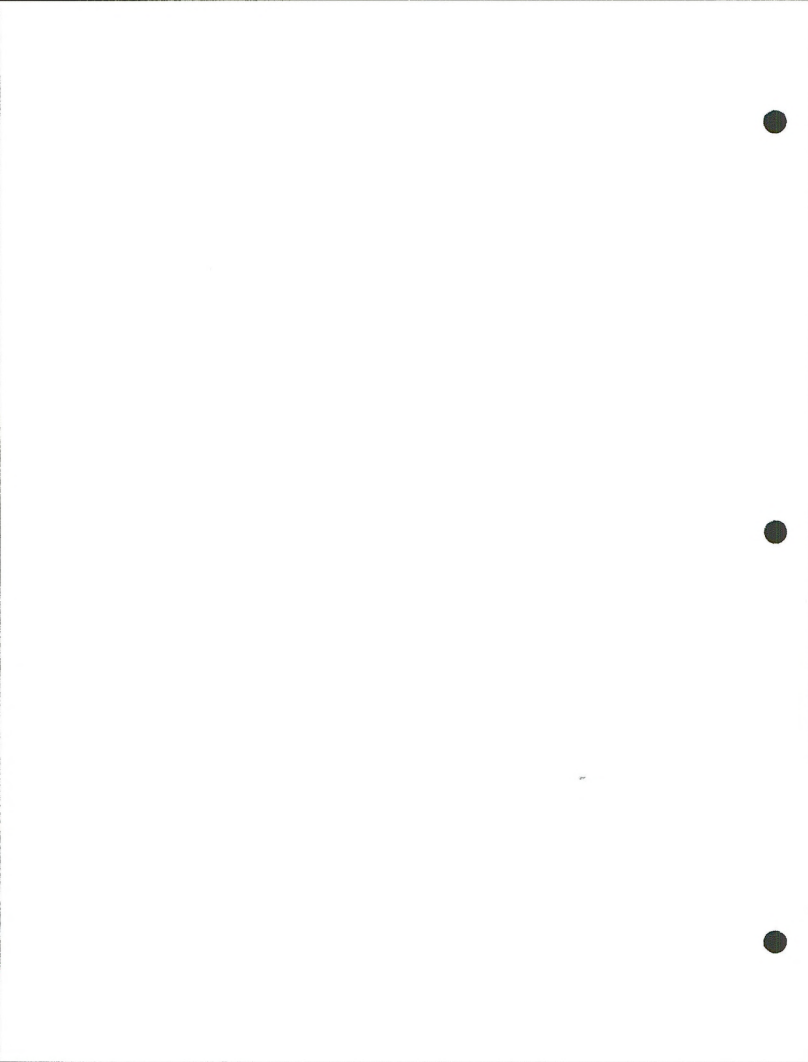
	<u>Concentrations, ppb</u>		
	<u>Retort Zero</u> <u>Retort Water</u> <u>February 1981</u>	<u>Retort One</u>	
		<u>November 1982</u>	<u>June 1983</u>
<u>Acid Extract</u>			
2-4 Dimethylphenol	395	92	25
Phenol	163	95	ND
<u>Base/Neutral Extract</u>			
Acenaphthene	7	ND	ND
Isophorone	40	ND	ND
Pyrene	3	ND	ND
Naphthalene	---	ND	15
<u>Volatile Compounds</u>			
Benzene	---	30	86.5
Toluene	---	29	38
Ethylbenzene	---	ND	10



organics will probably be present in any leachate from MIS retorts. These organics analyses have been examined for indications of possible human and environmental health hazard. There is little, if any, toxicological information on many of the compounds identified in the GC/MS analysis (Table 12). However, an evaluation can be made based on hazard information for similar compounds or for classes of compounds as follows:

- o Aliphatic monocarboxylic acids - These compounds present no significant health hazards. Many of them are naturally occurring in foods, are allowed as food additives, or are found in normal metabolic pathways in humans and animals.
- o Aliphatic dicarboxylic acids - Again, these compounds would not produce toxic effects at the levels present. Ethanedioic (oxalic) acid can form the insoluble calcium salt, while propanedioic (malonic) acid can be an enzyme inhibitor, but at these levels should not be significant. The compounds are readily metabolized.
- o Aromatic acids - These should be readily metabolized and present no significant health hazard.
- o Phenols - Phenol and the cresols are toxic at higher doses, but the low levels are well within the water quality criteria.
- o Aromatic amines - This is a mixed group of compounds of varying toxic hazards. There is little or no information on many of the compounds listed under the category of aromatic amines, especially the isomers.

Aniline and aminotoluene can alter the oxygen-carrying capacity of blood and have other toxic effects at higher dose levels, but should have no significant toxic effects at the levels present. Pyridine



and the substituted pyridines have a low toxicity when administered as single oral doses to rodents, and a trimethyl pyridine is approved by FDA as an indirect food additive. No toxic effects are expected at the levels present.

Quinoline and isoquinoline have been identified as rodent carcinogens and would, therefore, be considered suspect human carcinogens. However, they are present at very low levels and the risk would probably be very low. No information is available on the substituted quinolines and isoquinolines. Acridine has a low acute oral toxicity; there is no information on the other polyaromatic or hydroxylated pyridine derivatives.

N-Phenylbenzene amine, or diphenylamine, and its isomers are considered less toxic than aniline, and therefore, no significant toxic effects would be expected at the levels present. There is no toxicity information on carbazole.

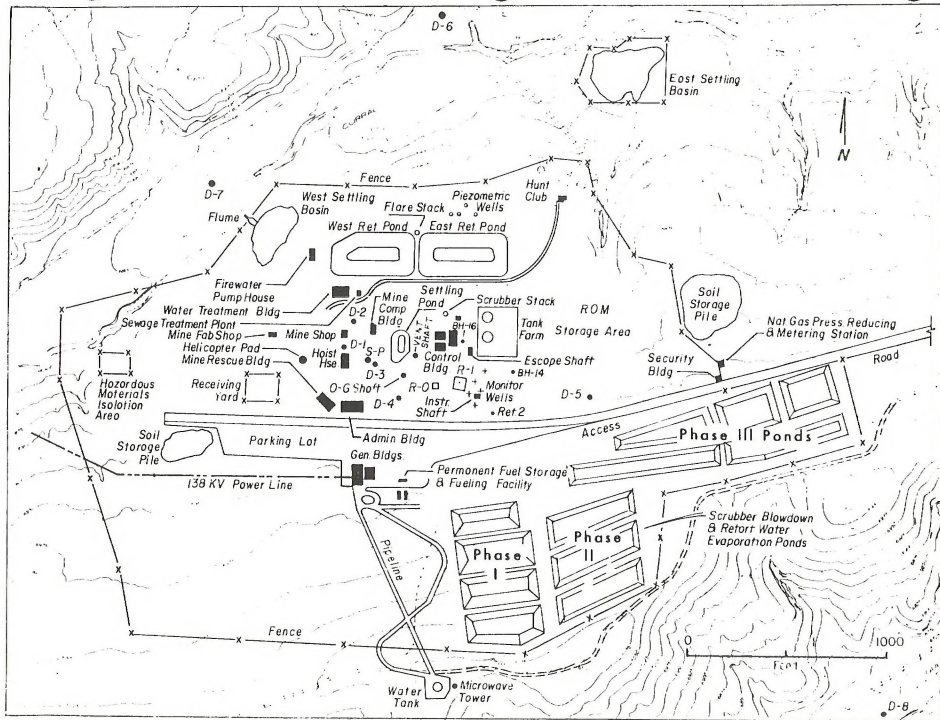
Among the priority pollutants determined (Table 13), the major concerns would be for acenaphthene, pyrene, and benzene. Of these only benzene has been observed in retort leachate. Although acenaphthene is a rodent carcinogen, the level identified is well below the water quality criteria. The levels of benzene and pyrene both exceed the water quality criteria. However, these criteria are for lifetime exposure in drinking water and consumption of aquatic organisms.

In conclusion, within the limits of the available information, there does not appear to be any compounds present in retort leachate at levels sufficient to individually produce significant toxic effects.



5.6 References

- o Law Engineering Testing Co., 1981. Development of Source Term Models - MIS Closure Study.
- o E. T. Huang "Groundwater Leaching of Total Dissolved Solids from MDP Spent Retorts - A Computer Simulation Study", Exhibit 14.
- o W. Fred Ramirez and H. Abedi, 1979, Impact of In Situ Spent Shale Leachate on Ground Water Quality for Modular Development Phase of Tract C-a, for Colorado Water Quality Control Commission.
- o Peterson, et. al. 1982, Assessment of Water Contamination Associated with Shale Oil Extraction and Processing, LASL Report LA-9084-PR, April 1982.
- o Rio Blanco Oil Shale Company, Environmental Monitoring Scope of Work, December 1980. Submitted to OSO.



Tract C-a Surface Facilities
Figure 1



Evaporation Pond Volume Start Abandonment 1/01/84

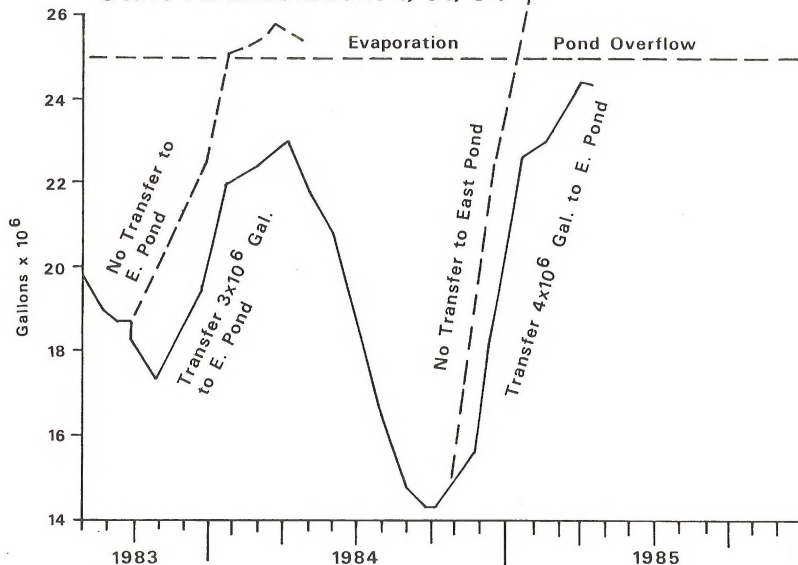
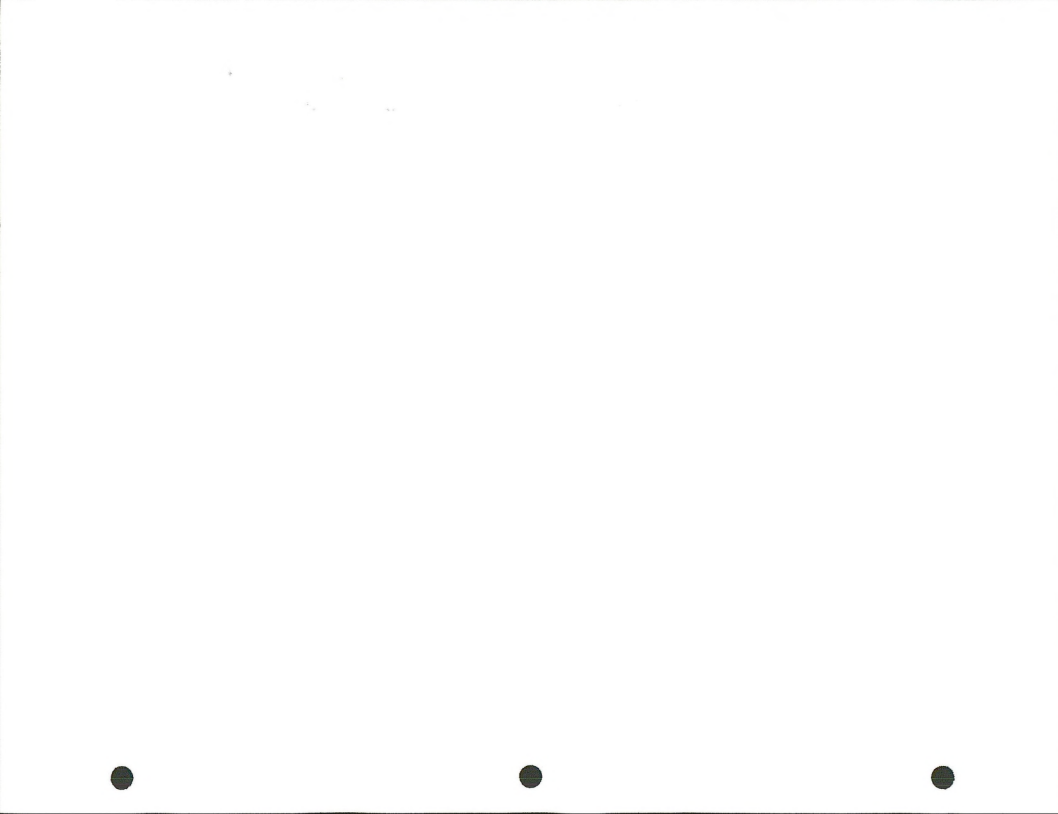


Figure 2



East Pond Water Volume

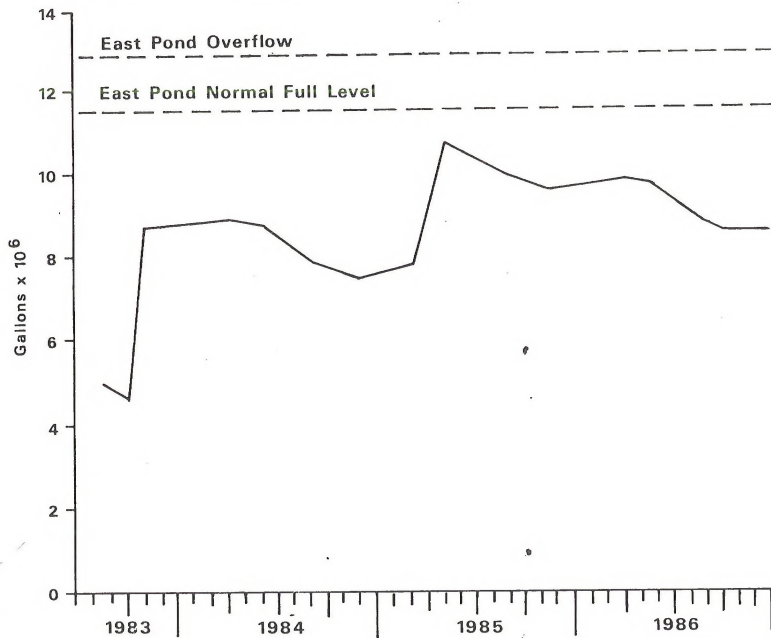


Figure 3



Water Level in Well MDP-2C

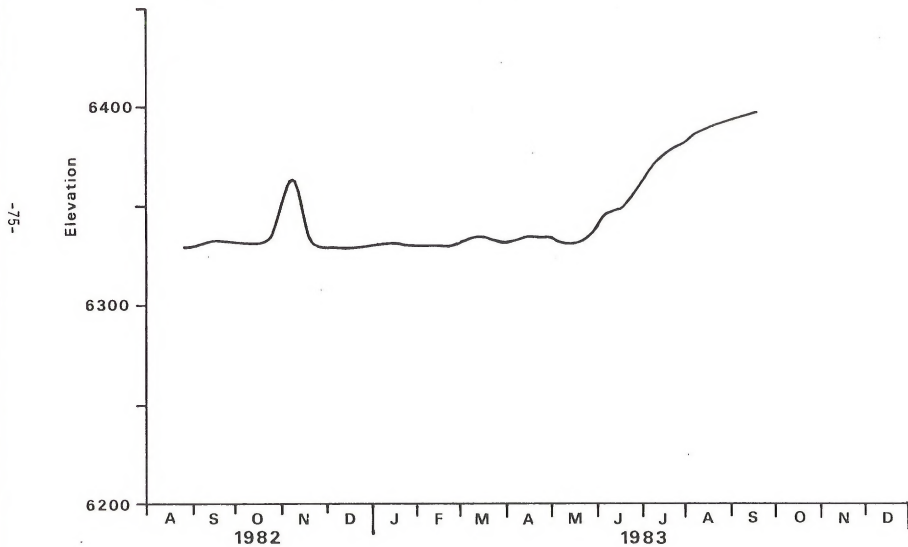


Figure 4



Water Production from Mine

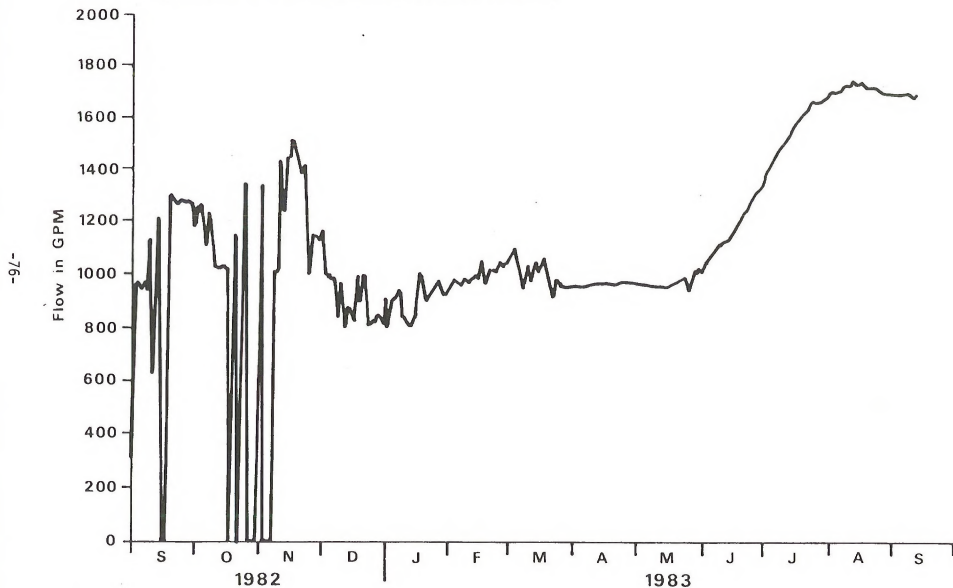


Figure 5



Water Levels in Mine Shaft

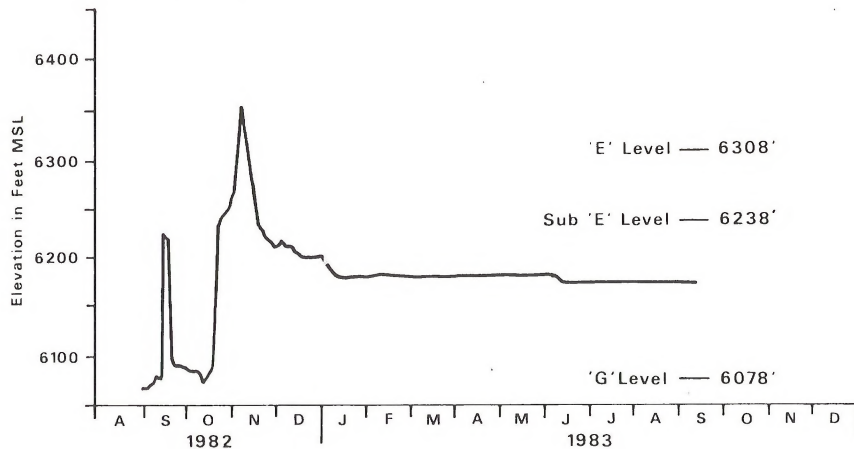
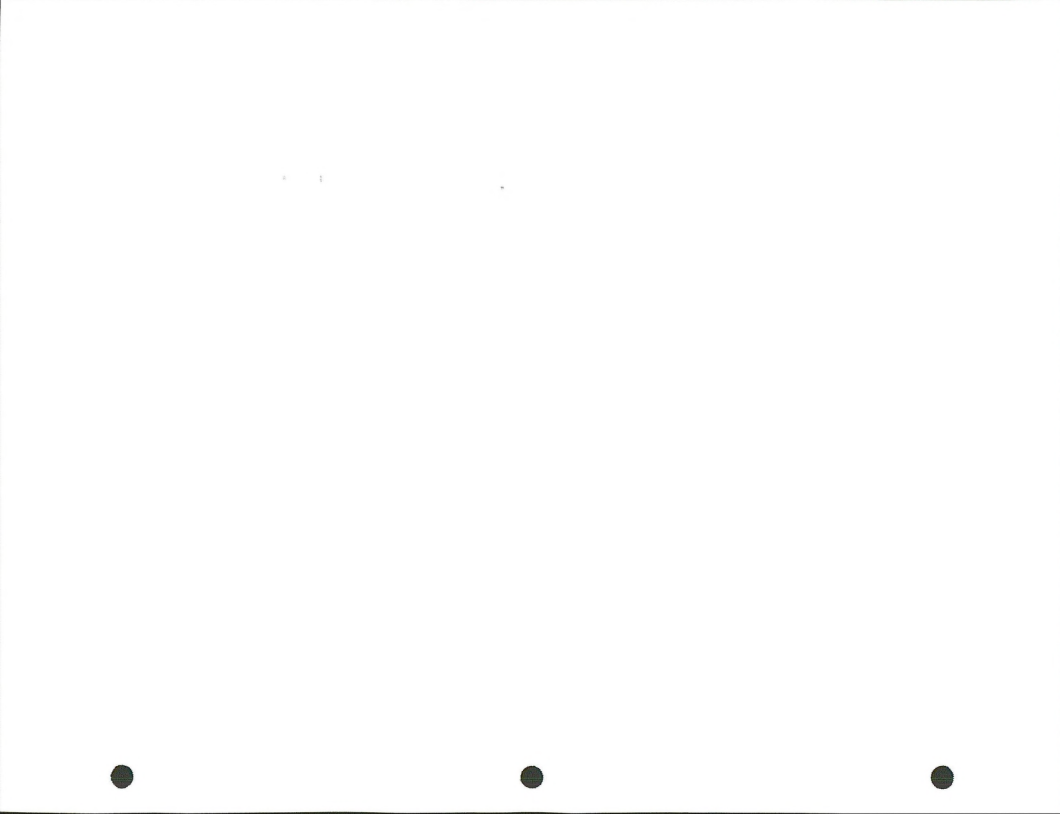


Figure 6



Water Flow into Retorts

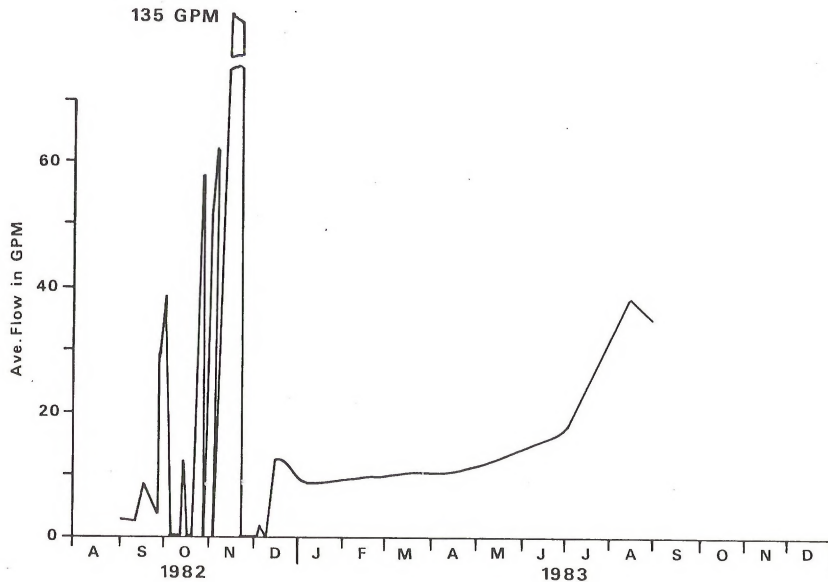


Figure 7



Water Level in Retorts

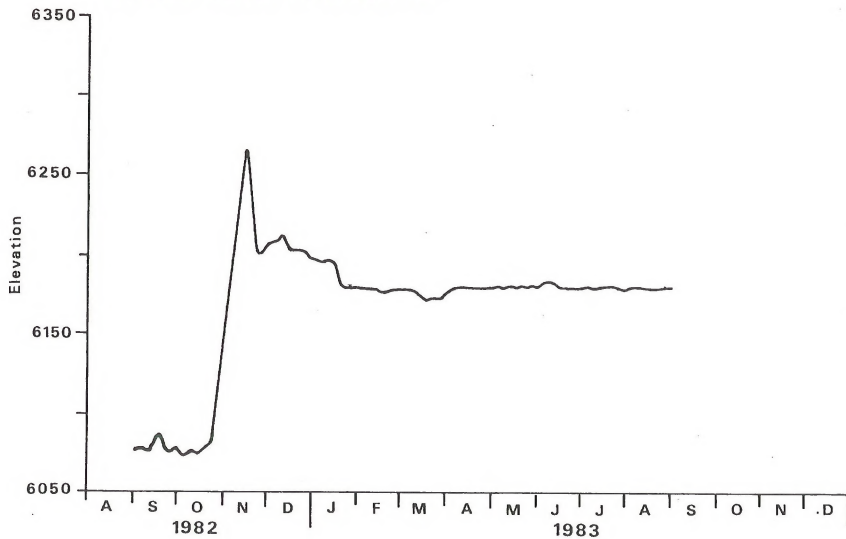


Figure 8



Retort Water Specific Conductance

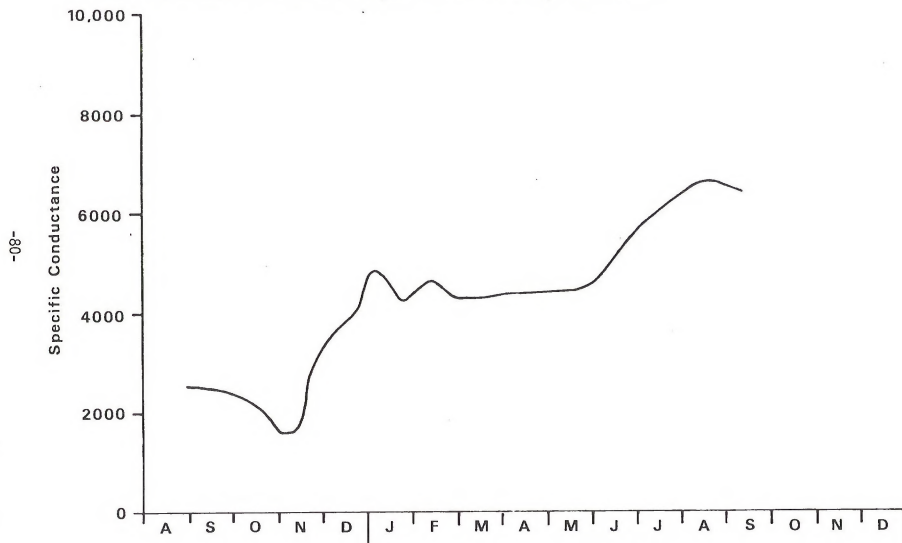


Figure 9



Retort Water Temperature & pH

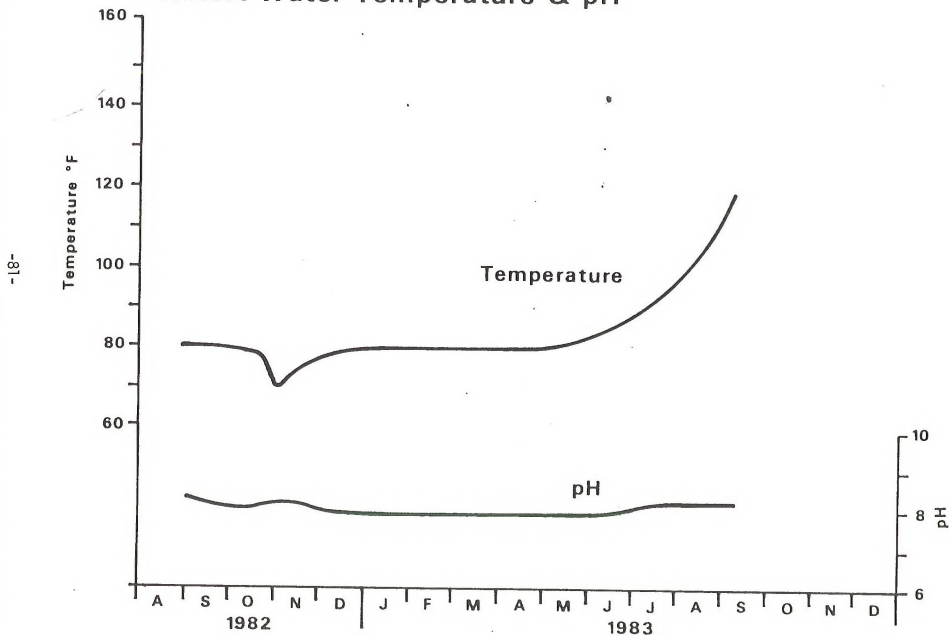


Figure 10



Retort Leachate Chemistry

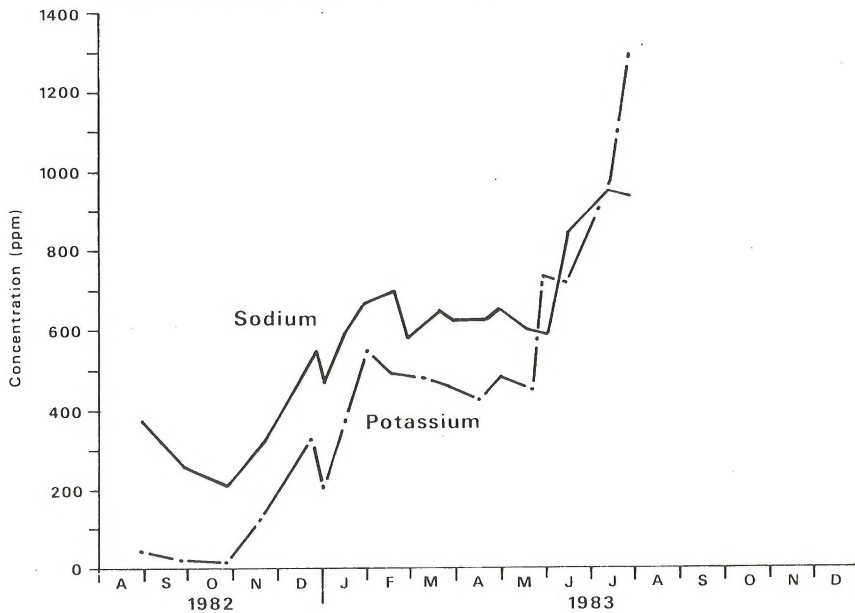


Figure 11



Retort Leachate Chemistry

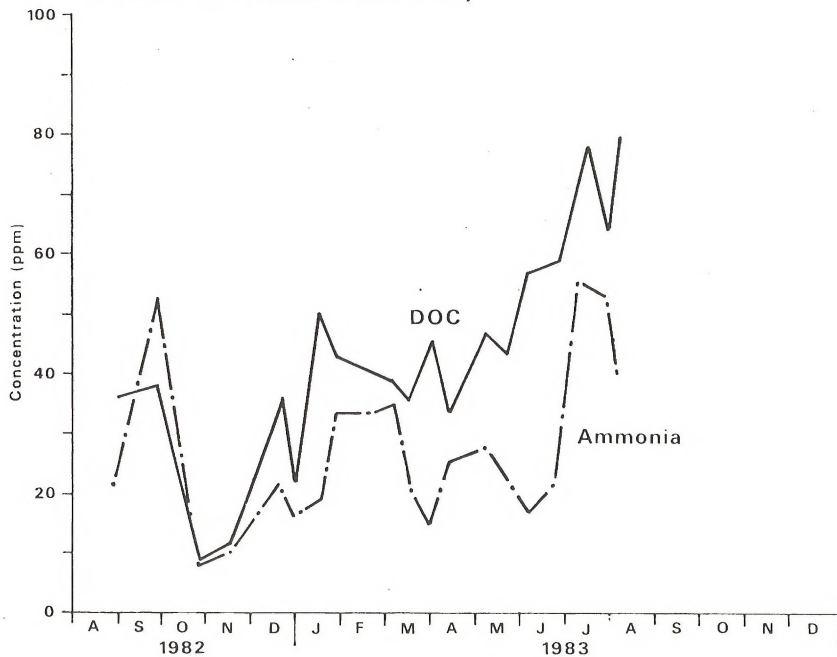
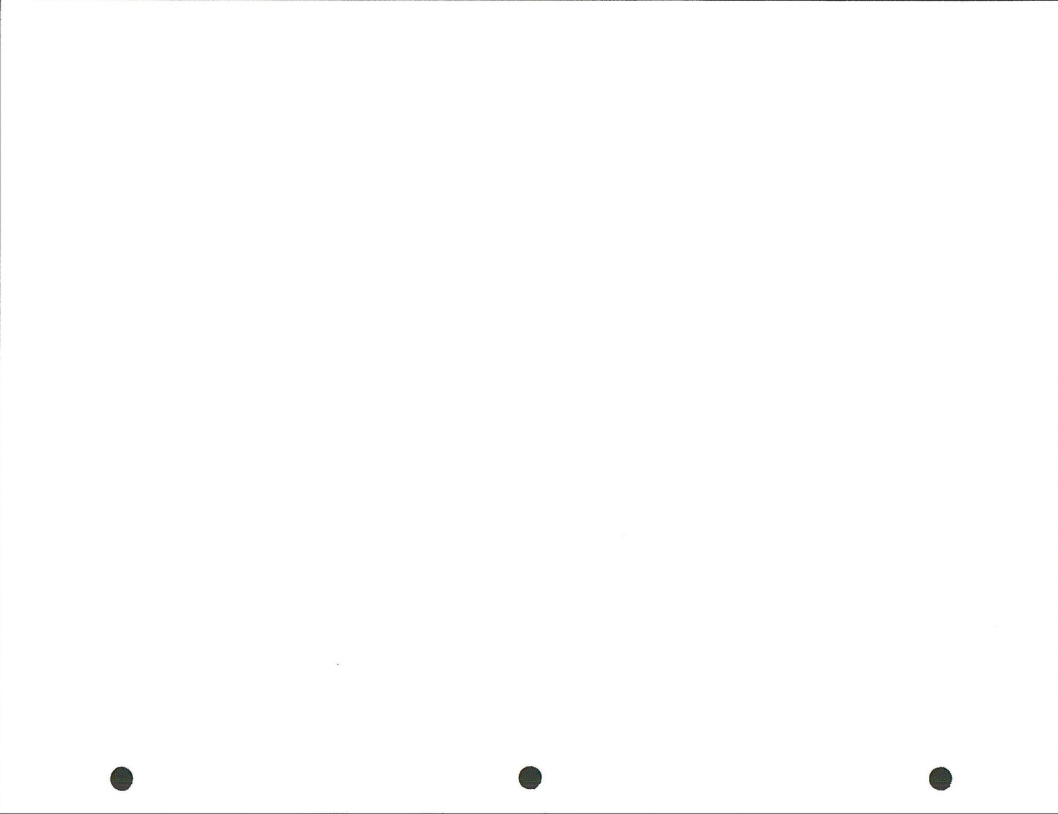


Figure 12



Retort Leachate Chemistry

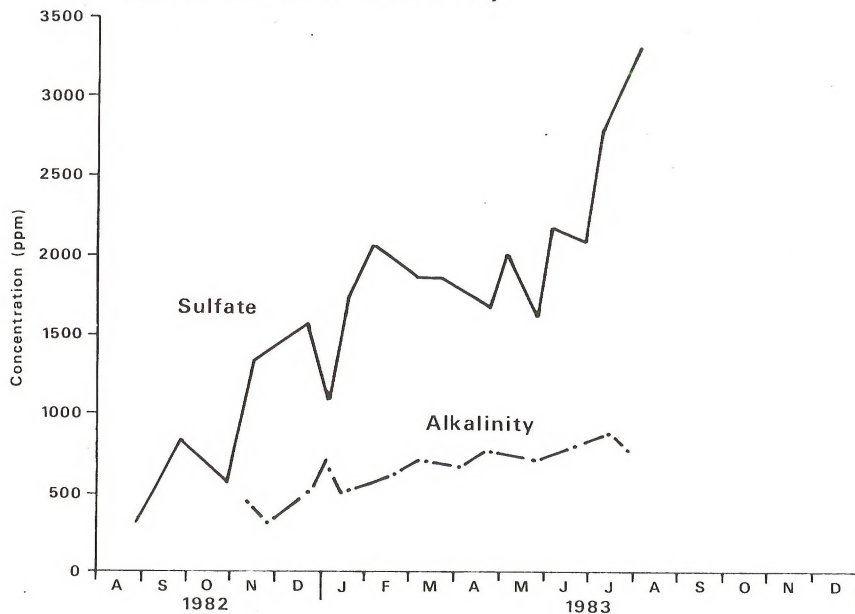


Figure 13



Retort Leachate Chemistry

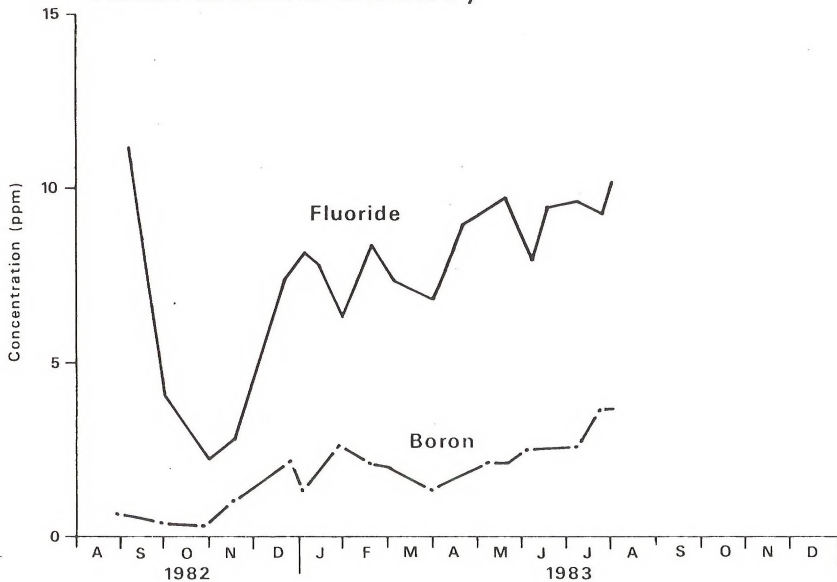
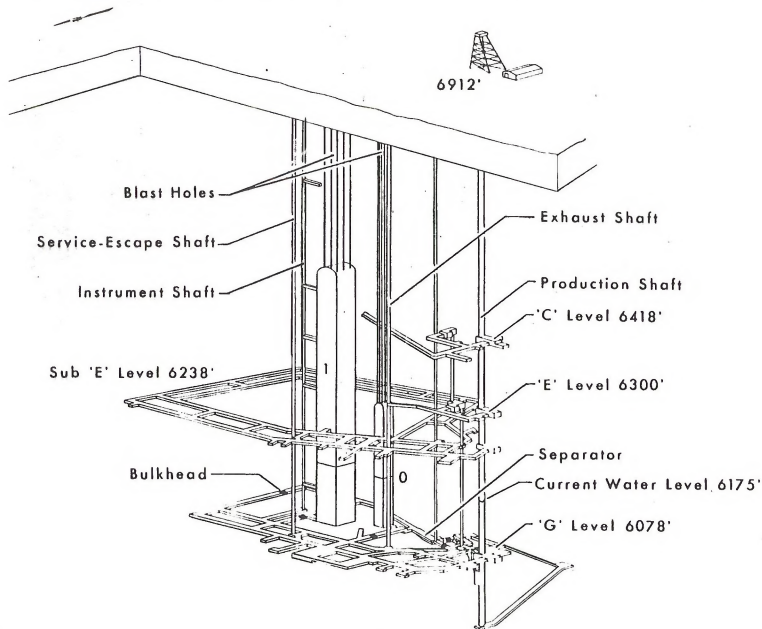


Figure 14





Mine and Retort Plan
Figure 15

